FINAL REPORT

DEVELOPMENT OF AN INVENTORY OF MATERIALS POTENTIALLY SENSITIVE TO AMBIENT ATMOSPHERIC ACIDITY IN THE SOUTH COAST AIR BASIN

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The contractors developed an inventory of exposed materials for residential and non-residential buildings and nonbuildings. The inventory of the residential buildings was developed by conducting telephone surveys of 1,200 households and field surveys of 200 households. The inventory of multi-family residential buildings and nonresidential buildings was conducted by aerial photo analysis. The inventory of nonbuilding materials (infrastructure) was developed by conducting a limited survey and by using engineering calculations. The investigators extrapolated the inventory to the entire SoCAB using the building-count method.

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ABSTRACT

This study demonstrates a methodology which permits the development of a comprehensive inventory of materials-in-place in an urban region, within a practical scope of work and with verified reliability. This methodology has been successfully applied to produce an inventory, for the South Coast Air Basin, of potentially susceptible materials exposed to the urban atmosphere. It involves separate treatment of three types of facilities, with specific protocols for each type. The three types of facilities, in which almost all of the susceptible materials are found, are (1) single-family residences (SFRs); (2) non-residential buildings and multiple-unit residential buildings, collectively called non-single-family residences (NSFRs); (3) structures other than buildings, collectively called Infrastructures.

Out of two and a quarter million SFR parcels recorded in the tax assessor data bases in the SoCAB, a representative sample of 1200 households were selected and surveyed by telephone regarding exterior surface materials of buildings and ground covers. Subsequently, a field survey of 200 houses selected from those surveyed by telephone was conducted to make detailed on-site measurements of all exterior material-finishes. For NSFRs, out of 3855 tax assessor mapbooks over the SoCAB, 30 mapbooks were selected and the corresponding regions were examined using aerial photographic method. With a camera system mounted on a light aircraft, a total of 2000 low altitude, oblique photographs were taken and analyzed to evaluate exposed material surfaces of 1429 NSFR parcels selected from those in the 30 study sites. Materials associated with infrastructures such as highways, railroads, channelized waterways and power distribution networks were quantified by estimating three basic quantities: the total miles of infrastructure facilities; the number of material-bearing items associated with the facilities; and the material factors for such items. Estimates of the three quantities were made either by conducting a special survey (for highways), by taking on-site measurements of a few selected items of each type, or by obtaining enumeration statistics from appropriate data source organizations.

Based on these three separate analyses, a reliable, highly resolved, comprehensive inventory of materials-in-place was developed for the entire SoCAB region.

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GLOSSARY

AGR	Agricultural parcel
ARB	California Air Resources Board
CALTRANS	California Department of Transportation
CBD	Central Business District
Cluster	A collection of contiguous NSFR parcels that share a common building or building complex.
COMP	Composite County that consists of counties of Orange, Riverside and San Bernardino
COL	Collector streets in urban area
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
HPMS	Highway Performance Monitoring System, a major data base managed by CALTRANS
HWY	Highways and surface streets
LMFR	Large multi-family residential parcel having 5 or more dwelling units
LNR	Large non-residential parcel that includes balance of NR excluding those found in SNR
LOC	Local streets in urban area
MA	Minor arterial streets in urban area
Mapbook	Highest hierarchical unit used by tax assessors to indicate geographical location of a parcel
MED	Time period for buildings built in years between 1946 and 1964
MFR	Multi-family residential parcel having triplex or more dwelling units
MH	Mobile homes
MJC	Major collector streets in rural area
MJR	Major properties identified by Los Angeles tax assessor office
NAPAP	National Acid Precipitation Assessment Program
NEW	Time period for buildings built in 1965 or later years
NR	Non-residential parcel

NSFR	Non-single family residential parcel that includes all parcels other than SFRs
OI	Other infrastructures that include railroads, channelized waterways, and power distribution networks
OLD	Time period for buildings built in 1945 or prior years
PA	Principal arterial streets in urban area
Parcel	Basic land plot used by tax assessors
RCOND	Residential condominium
SFR	Single family residential parcel that includes single detached house and duplex
SJSU	San Jose State University
SMFR	Small multi-family residential parcel that includes triplex and fourplex
SNR	Small non-residential parcel such as service stations, nurseries, parking lots, etc.
SoCAB	California's South Coast Air Basin that consists of Orange County and portions of three other counties: Los Angeles, Riverside and San Bernardino
UNK	Parcel with unknown use
VAC	Vacant parcel
VRC	Valley Research Corporation

1.0 INTRODUCTION

1.1 BACKGROUND AND STUDY OBJECTIVE

The Kapiloff Acid Deposition Act of 1982 mandates the Air Resources Board (ARB) to conduct a comprehensive research program to determine the nature, extent, and potential effects of acid deposition in California. Part of this far reaching effort is the need to accurately assess the economic impact that acid deposition has upon materials in place. To make such an assessment possible, ARB has sponsored a series of research projects which are aimed to obtain the following information:

Material Damage Functions to quantify marginal rates of material deterioration (e.g., metal corrosion and paint erosion) due to air pollution;

Materials Inventory to quantify and characterize materials-in-place which are exposed to ambient air; and

Replacement Costs to quantify marginal costs of replacing, at an accelerated rate, items containing those materials which are susceptible to acid deposition.

The present study is concerned with developing a reliable, comprehensive inventory of materials-in-place. A previous ARB-contract study (Murray *et al*. 1985) developed a preliminary inventory of several economically significant materials in place in the South Coast Air Basin (SoCAB). The study, however, was limited with respect to the level of detail and the number and types of materials considered. Therefore, the main objective of this study is to develop for the SoCAB an improved, more comprehensive inventory of materials that are potentially susceptible to damage from atmospheric acid deposition.

Although it is a part of the overall study of assessing the economic impact of acid deposition upon materials, the scope of this study is not limited to only those materials which are being investigated under the ARB-sponsored materials damage studies or those which will be examined under a forthcoming economic assessment study. Since it is not wise to presume economic loss due to acid deposition in the basin occurs predominantly in one type of material rather than another, this inventory study aims to characterize all types of materials that are present in significant quantity and are potentially susceptible to damage by acid deposition.

Further, the inventory developed under this study specifies not only what amounts and types of materials are in use but also what types of facilities* and what structural components the materials are used for. The rate of damage to a material due to acid deposition may depend, in part, on how and where, in the facility, the material is used. In addition, the replacement cost for a material may partially depend on the type of facilities in which the material is used.

Because of the importance of knowing the types of facilities as well as the types and amounts of materials-in-place, this study is designed to quantify materials-in-place in relation to specific types of facilities. There are three main types of facilities in which the great majority of materials are found:

1. Single Family Residences (SFRs), including single detached houses and duplexes;

2. Non-Single Family Residences (NSFRs), including multi-family residences and non-residential buildings; and

3. Infra-Structures, including roadways, electrical distribution networks, railroads, and channelized waterways.

1.2 SUMMARY OF FINDINGS

The most important result of this study is probably the demonstration of a methodology which permits the development of a comprehensive inventory of materials-in-place in an urban region, within a practical scope of work and with verified reliability.

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* Here, "facilities" mean any man-made material bearing complexes such as residential buildings (including various associated minor structres), commercial buildings, industrial plants, institutional complexes, highways, surface streets, railroads, channelized waterways, and transmission and distribution towers.

This methodology has been successfully applied to produce an inventory, for the South Coast Air Basin, of potentially susceptible materials exposed to the urban atmosphere. It involves separate treatment of three types of facilities, with specific protocols for each type. The three types of facilities, in which almost all of the susceptible materials are found, are (1) single-family residences (SFRs); (2) non-residential buildings and multiple-unit residential buildings, collectively called non-single-family residences (NSFRs); (3) structures other than buildings, collectively called Infrastructures.

For each of these types of facilities, VRC devised and applied an appropriate sampling frame and a corresponding inventory procedure. These developments are fully described in Chapter 2.0, and further details regarding the execution of the surveys, as well as brief summaries of the results, are reported in Chapters 3.0, 4.0 and 5.0. Highlights of VRC's experience and findings in preparing the subject inventory are set forth in the following paragraphs.

1.2.1 SFR SURVEY FINDINGS

- Out of two and a quarter million SFR parcels in the SoCAB, 3825 SFR households with listed telephone numbers were selected by a stratified random sampling method.
- Of the 3825 households, a telephone questionnaire survey on exterior surface materials of buildings and ground covers was attempted for 2095 households and completed on 1200 households, a completion rate of 57 percent.
- Of the 1200 households so surveyed, 259 houses were selected as "target" houses for a subsequent field survey. The field survey was completed on 176 target houses (68 percent completion rate) and 24 substitute houses which were selected from houses having the same structural features as target houses in the immediate neighborhood. In all, the survey was completed on 200 houses.
- Comparisons between questionnaire responses and field observation results indicate that the questionnaire-responses are reliable for questions about presence or absence of features, questions on building configuration, and questions on materials used for chimneys, garage walls, and ground cover.
- Reliability of the field survey was examined by comparing survey results on three test houses for which two survey teams of two surveyors each made on-site measurements twice; first, separately by

each team and second, jointly by both teams. The comparison revealed that relative measurement errors were within 10 to 20 percent for major components. For some material-finishes, the two teams identified them differently, indicating that misidentification of material-finishes can in some instances be a primary source of errors.

- The mean livable space of the 198 houses (2 houses were later excluded from the data base) is 1500 ft^2 whereas the mean total building exterior surface area is 5500 ft^2 and the mean total exposed surface area of SFR parcels is 9100 ft^2.
- Of the building primary surface of 5500 ft^2, roofs account for 43 percent, basic walls for 36 percent, soffits for 12 percent, and walls and doors for 9 percent.
- Houses in Los Angeles County were examined separately for OLD (pre-1946), MED (1946-1964), and NEW (post-1964). Houses in NEW have the largest livable space (1900 ft^2), the highest proportion of two-story houses (50 percent), and the least proportion of detached garages (11 percent). Conversely, houses in MED have the least livable space (1450 ft^2), and the least proportion of two-story houses (8 percent). Houses in OLD have the highest proportion of detached garages (80 percent).
- As to exterior surface materials, houses in NEW have the largest amounts of bare concrete (for ground cover), painted stucco (for wall), block and chain link (for fence), and painted wood (for trim, eave, etc.). Conversely, house in MED have the least amounts of bare concrete and painted wood. Houses in OLD have the least amount of block but have the largest amount of brick.
- As to roofing materials, houses in OLD have the largest amount of asphalt roofing (i.e., shingle) but the least amount of tar. On the other hand, houses in NEW have the least amount of asphalt roofing but the largest amount of terra cotta (i.e., Spanish tile). Houses in MED have the largest amount of wood shingle.
- Total exposed material surfaces associated with SFRs in the SoCAB are estimated to be 20 billion ft^2, of which the most common material-finish is painted wood (16 percent), followed by painted stucco (15 percent), bare asphalt (13 percent), bare concrete (11 percent), bare wood shingle (7 percent), and bare block (6 percent).
- Basin total painted surface is estimated to be 7.1 billion ft^2, of which the preponderant material is wood (47 percent), followed by stucco (43 percent), aluminum (5 percent and concrete (2 percent).

1.2.2 NSFR Survey Findings

- Out of 3855 tax assessor mapbooks over the SoCAB, 30 mapbooks were selected representing sites to be examined using the aerial photographic method (hereafter called "airphoto method"). Of the 30 mapbooks, 20 were in Los Angeles County and 10 in Composite County, which consists of Orange County and SoCAB portions of Riverside and San Bernardino County.

- Using the Enviro-Pod camera system mounted on a light aircraft, a total of 2000 low altitude, oblique photographs were taken and analyzed to evaluate exposed material surfaces of NSFRs in the 30 mapbook areas.
- Of 12,235 NSFR parcels contained in the 30 mapbooks, in the parcel file phase, 6348 parcels were analyzed with respect to building height and size and ground cover materials. In the building file phase, 1429 parcels selected from those in the parcel file were analyzed in detail using low altitude, oblique airphotos and cadastral maps.
- Among the eight NSFR use-types (SMFR, LMFR, RCOND, SNR, LNR, MJR, UNK, VAC) examined for Los Angeles County, VAC exhibited the highest proportion (53 percent) of parcels without buildings, followed by SNR with 39 percent. The average percentage of no-building parcels in Los Angeles County is 9.5 percent. In Composite County, such no-building parcels account for 27 percent of all NSFR parcels, with the three highest percentages, 87 for VAC, 49 for UNK and 29 for AGR.
- For parcels with buildings, the construction type of dominant building in each parcel was identified: wooden post lintel (Wood), masonry (Masonry), concrete (Concrete), or steel reinforced frame (Frame). "Wood" is the most numerous, accounting for 64 percent and 69 percent, respectively, in Los Angeles and Composite Counties. "Frame" is the least numerous, composing only 6 percent and 2 percent of NSFR parcels in Los Angeles and Composite Counties.
- In terms of floor space per parcel, "Wood" is the smallest, having 7200 ft^2 and 13,000 ft^2 in the two counties whereas "Frame" is the largest (46,000 ft^2) in Los Angeles County and "Concrete" is the largest (33,000 ft^2) in Composite County.
- Compared to SFRs, NSFRs have considerably greater exposed material surfaces except for VAC and MH whose surface areas are smaller than the SFR's 9100 ft^2: 41,000 ft^2 for MJR to 14,000 ft^2 for SMFR in Los Angeles County; and 41,000 ft^2 for UNK to 17,000 ft^2 for RCOND in Composite County
- The mean exposed surface of NSFR parcels in Composite County is considerably greater than that for Los Angeles County: 27,000 ft^2 vs. 18,000 ft^2. In Composite County, ground cover accounts for the most (10,050 ft^2), followed by Roof (8900 ft^2) and Wall (7100 ft^2). In Los Angeles County, Roof accounts for the most (7000 ft^2), followed by Ground Cover (5700 ft^2) and Wall (5200 ft^2).
- In the SoCAB, the total number of NSFR parcels with buildings is estimated to be 810,000. Basin total exposed surfaces of these NSFRs are estimated to be 14.5 billion ft^2 as compared to 20.5 billion ft^2 for all SFRs. NSFRs in Los Angeles County have 8.4 billion ft^2 and those in Composite County 6.1 billion ft^2.

- The preponderant materials are asphalt roofing (35 percent/25 percent in Los Angeles and Composite Counties), bare asphalt (18/28), painted stucco (14/14), and bare concrete (14/8).

1.2.3 INFRASTRUCTURE FINDINGS

- Materials associated with highways and other infrastructures such as railroads, channelized waterways and power transmission/distribution networks were estimated from the number of material-bearing items in those infrastructure facilities and the material factors, which were determined by taking detailed measurements on a few typical items of each type.
- The numbers of material-bearing items for surface streets were estimated by conducting a special street survey for a total of 47 survey routes covering 282 miles whereas those for state highways were obtained from CALTRANS local district office in Los Angeles.
- In the SoCAB, the total exposed material surfaces (excluding road surface) associated with highways are estimated to be 1.6 billion ft^2, of which the predominant materials is concrete (87 percent) and. The rest are unspecified metal (6 percent), chain link fence (5 percent), galvanized steel (1 percent), and steel (0.6 percent).
- The total exposed material surfaces associated with other infrastructures are estimated to be 0.6 billion ft^2, of which the predominant materials are bare wood (48 percent) and concrete (26 percent). The remaining materials are galvanized steel (13 percent), chain link fence (8 percent), and steel (5 percent).

2.0 OUTLINE OF STUDY APPROACH

Prior to the present study, several material inventory studies have been conducted in the U.S. Northeast and Midwest, Canada, and the SoCAB. Although each contributed significantly to the development of materials inventory methodology, these earlier studies invariably failed to produce a reliable, comprehensive inventory of materials-in-place. By incorporating lessons from the failures of the earlier studies, this study has advanced the state-of-the-art inventory methodology so as to generate a reliable, comprehensive inventory of materials-in-place in the SoCAB.

This section critically reviews earlier inventory studies and then discusses the sampling frames, survey designs and measurement schemes which were used for quantifying materials associated with single family residences (SFRs), non-single family residences (NSFRs) including all types of buildings other than those in SFR parcels, and infrastructures (IRs) including roads, railroads, power distribution systems, and channelized waterways.

2.1 REVIEW OF EARLIER STUDIES

While the science of corrosion and other material damage processes has been developed over many years, the materials inventory question has received detailed and systematic study only recently. Among studies conducted since the late seventies, the following paragraphs outline the five major studies on materials inventory:

EPA Study: McFadden and Koontz (1980) made the first systematic study of materials inventory. They used as the primary data source fire insurance maps covering the study area. Unfortunately, these maps appear to have been outdated, leading to unreliable estimates and probably gross under-estimates of the most sensitive but sparsely distributed materials, such as galvanized steel and marble.

EPRI Study: For the Greater Boston area, Stankunas et al (1983) used small (100 ft x 100 ft) land area samples which intersected building boundaries. Unfortunately, they worked with an unstratified sample, creating excessive variance and many vacant sites (49%) having zero material content.

According to Daum and Lipferd (1984), who reanalyzed the study data, the results were incorrectly extrapolated to apply to the entire metropolitan area.

ARB Study: Murray, et al (1985) attempted an inventory in SoCAB but had difficulties with insufficient field observations and thus with the subsequent extrapolation. However, this work did generate the seminal suggestion of using census-tract-average building age and family income as predictor variables for residential housing materials.

CANADIAN Study: The Leman Group (1985) carried out a pilot inventory effort in Toronto using land area as an extrapolation basis. The study utilized aerial photographs in developing a gridded urban terrain map and paid special attention to architectural details for NSFR buildings. However, the statistical basis for their approach has not been verified nor have any sampling or extrapolation errors been estimated.

NAPAP Study: Merry and LaPotin (1985) carried out a series of building surveys for two New England cities (Portland and New Haven) and two midwest cities (Pittsburgh and Cincinnati). Their surveys were based on the use of a stratified systematic unaligned random sample, using strata defined on the basis of both USGS land use categories and census data (Rosenfield 1984 and 1985). However, as the 1985 NAPAP Assessment developed, it became apparent that a building-count basis was preferable to a land area basis for extrapolating to unsampled areas (Daum et al 1986).

This review of the earlier studies indicates that there is yet no established methodology that can adequately treat all important aspects of surveying, mapping, and extrapolating materials-in-place to a large geographical region like SoCAB. The methods based on pre-existing data like census housing statistics and fire insurance maps suffer from the fact that these data do not cover the entire population of buildings and other important structures. On the other hand, the methods based on "footprints" (land-area samples) suffer from the inefficiency associated with many empty cells if the footprints are small, and from sampling bias associated with multiple buildings in a cell if large footprints are used. Furthermore, results of the land-based survey cannot be readily extrapolated to unsampled areas.

2.2 PRESENT STUDY APPROACH

A deficiency of all the studies reviewed above appears to lie in the weakness of the sampling frames on which the survey designs and measurement schemes were based. This deficiency probably resulted from optimistic assumptions regarding their survey designs and measurement schemes. For example, the NAPAP study (Merry and LaPotin 1985) assumed that materials found within a sample of randomly placed footprints would provide both a representative mix and representative quantities of different materials in place. However, it was found that such an assumption was unsupported by the survey data they gathered. Later, their land-based data were converted into building-related data in order to allow for extrapolation to the study region (Daum et al 1986).

Another deficiency lies in the incompleteness of their observational data. For example, Murray et al (1985) surveyed 90 houses in the SoCAB by taking pictures of only the fronts of their houses; then, generated observational data of materials-in-place based on the pictures and field notes taken at the sites. No on-site measurements were taken except the distance between the photographer's position and the house. Deducing from the pictures both dimensions of and materials present at various components of the house is quite imprecise, particularly for unseen areas like the back of the house and structures in the backyard.

By learning from the deficiencies and shortcomings of earlier materials inventory studies, this study has focused its efforts on the following three areas:

<u>Sampling Frame</u> Since materials are present as a part of a facility containing them rather than by themselves, we define separate frames for different types of facilities, namely, SFRs, NSFRs, and Infrastructures;

<u>Survey Design</u> For the three sampling frames, separate surveys are designed in a rigorous manner so that a representative sample is drawn from each sampling frame; and

<u>Measurement System</u> Recognizing known limitations of quantifying and characterizing materials-in-place, the most appropriate measurement system is devised for each conceivable assemblage of materials-in-place.

More detailed discussions of each of the above three areas are given in subsections that follow.

2.2.1 SAMPLING FRAME

Success in any survey-oriented study depends largely on a proper definition of the sampling frame for the survey. The NAPAP study (Merry and LaPotin 1985) used a land area as the sampling frame; that is, a unit of land area which they called a "footprint" was considered as a basic sampling unit and was selected in a random manner from the entire study area. This study area was divided into a few sub-areas having a similar housing density. Unfortunately, the amounts of materials found in a footprint are not readily comparable to quantities and types of materials associated with common facilities like houses and roads for which reliable statistics are available.

The previous ARB study (Murray et al 1985) used census tracts of the Census of Housing as the sampling frame. Unfortunately, the census data relate to housing units and not buildings. Furthermore, they do not include non-residential buildings. Since most data on materials are associated with buildings rather than with housing units, the census data do not provide a good sampling frame for this study.

For these reasons, the authors sought a better sampling frame to be used for this study. After reviewing various data sources, it was found that land parcels used in tax assessor records have better attributes as a sampling frame for surveying SFRs and NSFRs than other known data sources. In particular, tax assessor records have the following desirable attributes:

All-Inclusive Sampling Frame All buildings and structures except those associated with infrastructures belong to certain land parcels uniquely. Thus, the records provide all-inclusive sampling frames for materials associated with SFRs and NSFRs.

Readily Available Data Bases All four counties composing the SoCAB have computerized data bases of tax assessor records and make them available for public use. Similar availability is expected in other metropolitan areas in California.

Ready Population Characteristics Assessor records provide not only counts of SFRs and NSFRs but also types of SFRs and NSFRs and, in some cases (e.g., Los Angeles County) physical dimensions and age of buildings (i.e., year built). Therefore, they can be used to elaborate a survey design for SFR and NSFR surveys.

Because of these attributes, this study used tax assessor records of the four counties as a sampling frame for both SFR and NSFR surveys, which were conducted under this study.

2.2.2 SURVEY DESIGN

VRC purchased a full assessor data base from each of the four counties composing the SoCAB: Los Angeles, Orange, Riverside and San Bernardino. In total, 74 volumes of 2400-foot magnetic tapes containing over 3 million assessor records were subjected to data processing. Since data formats and parcel classification schemes differ somewhat from one county to another, a series of data compaction and standardization operations were performed on the original assessor records so as to obtain a manageable and inter-comparable data base for this study (see Interim Report by Horie and Shrope (1987) for more detailed discussion).

Three major data files were created from the tax assessor data bases:

Mapbook-Stat All land parcel records in the assessor data base were classified into a few VRC-defined use categories and then reduced to summary statistics of parcel counts by use category at mapbook level. (Every assessor record is identified by mapbook, page number, and parcel number);

SFR Mini-Universe A systematic 10-percent sampling of all SFR parcels was made to create SFR Mini-Universe. This mini-universe carries detailed data on every sampled SFR, including the owner's name, the street address, the city, the year built (Los Angeles County only), the total livable space (Los Angeles County only), and the full parcel identification number (hereafter called "parcel ID"); and

NSFR Full-Universe Some 300 data items of each NSFR parcel record in the assessor data base were reduced to only two data items; parcel ID and VRC-defined use type. A full universe of NSFRs in the SoCAB is retained in this file by the two data items.

Table 2-1 presents summary counts of mapbooks and parcels by use type in the SoCAB. The number of parcels in each county is already adjusted to the SoCAB portion of that county. Use types in the table are:

SFR = Single family residential parcel (single detached house and duplex);
MFR = Multi-family residential parcel (triplex or more units);
SMFR = Small MFR that includes triplex and fourplex;
LMFR = Large MFR that includes parcels of 5 or more units;
RCOND = Residential condominium;
NR = Non-residential parcel;
SNR = Small NR such as service stations, nurseries, parking lots, etc.;
LNR = Large NR that includes balance of NR excluding those found in SNR;
MJR = Major properties identified by Los Angeles tax assessor office;
MH = Mobile home;
AGR = Agricultural parcel;
VAC = Vacant lot;
UNK = Parcel with unknown use.

TABLE 2-1. NUMBER OF MAPBOOKS AND PARCELS BY USE TYPE IN EACH COUNTY OF THE SoCAB (as of June 1, 1986)

Use Type	Los Angeles	Orange	Riverside	San Bernardino	SoCAB
#Mapbooks	2,942	344	388	231	3,905
SFR	1,414,872	434,013	159,827	240,278	2,248,990
MFR	129,000	26,152	2,658	5,711	168,521
SMFR	(67,954)				
LMFR	(61,246)				
RCOND*	41,559	20,267	735	4,718	67,279
NR	167,825	38,685	8,570	25,859	240,939
SNR	(25,559)				
LNR	(119,604)				
MJR	(22,662)				
MH***	55,000	3,884	24,839	681	84,404
AGR	0**	526	9,757	2,597	12,880
VAC	126,680	38,782	92,952	73,884	332,298
UNK	3,027	110	6,609	1,051	10,797
Total	1,937,963	562,419	305,947	354,779	3,161,108
Percent of SoCAB	61.3	17.8	9.7	11.2	100

Note: Numerals in parenthesis are of sub-categories used only for Los Angeles County.

* Residential condominiums which had the same street address and were listed consecutively in the Los Angeles county assessor data base were reduced to a single parcel. This process yielded 3.9 condominium units per a common parcel. This correction factor was applied to condominiums in the other three counties as well.

** All agricultural type parcels in Los Angeles County are included in SNR category.

*** Mobile homes are not assigned parcel numbers in the assessor data base. These counts were obtained either from assessor office or from buried-in records in the assessor data base; they represent mobile homes and not assessed parcels.

According to the table, there are 3.16 million parcels in the SoCAB, of which 2.25 million parcels (71%) are SFRs. The balance is 0.91 million NSFRs which consist of various parcel uses such as multi-dwelling units (MFRs and RCONDs), non-residential parcels (NRs), mobile homes (MHs) and vacant parcels (VACs, parcels for new development, renewal or simply idled lots). A few parcels are for agricultural (AGR) and unknown (UNK) uses.

Among the four counties constituting the SoCAB, Los Angeles County accounts for 61 percent of the basin total, followed by the counties of Orange (18%), San Bernardino (11%) and Riverside (10%). Since Los Angeles County data are more detailed in use type than those of other counties, both SFR and NSFR surveys were designed and implemented separately for Los Angeles and for the other three counties. Hereinafter, the three counties are collectively designated as "Composite County".

2.2.2.1 SFR Survey Design

Although the "population" (in a statistical sense) of SFRs is much greater than the NSFR population, the former is expected to be more homogeneous in both building sizes and construction materials than the latter. Based on this assumption, the smaller number of survey samples was assigned to SFRs rather than NSFRs. On the other hand, higher accuracy in both identifying the types and determining the amounts of exterior materials was sought for SFRs than for NSFRs. As discussed in Section 2.2.3 - Measurement System, it was considered that accurate measurements can not be expected in a SFR field survey without physically entering each target property after first obtaining permission from the owner or occupant of the property. To ensure obtaining permission from all field survey houses, a screening survey (a telephone questionnaire on building features) was applied to the greater number of houses prior to the field survey. Another purpose of this questionnaire survey was to ensure that houses used for the field survey were indeed representative of the SFR population.

A two-stage, stratified random sampling method was applied separately to the SFR populations of Los Angeles County and of Composite County. Since the SFR universe of 2.35 million parcels was too large to be handled effectively, the SFR Mini-Universe consisting of 141,000 records for Los

Angeles County and 84,000 records for Composite County was used to select survey samples. To take advantage of both the higher cost effectiveness associated with questionnaire surveys and the higher accuracy associated with field surveys, VRC decided first to conduct a telephone questionnaire survey for 1,200 randomly selected houses and then to do a field survey for 200 houses which would be a subset of the 1,200 surveyed houses.

By analyzing SFR records of Los Angeles County, which contain data on "year built" and "total livable space", distributions of SFRs with respect to house size and age were examined so as to determine an appropriate stratification of the SFR population. This analysis and our general knowledge of house sizes and construction materials led to the eleven SFR strata as presented in Table 2-2.

TABLE 2-2. NUMBER OF SAMPLES ALLOCATED TO EACH OF THE 13 STRATA USED FOR QUESTIONNAIRE AND FIELD SURVEYS

County/ Stratum	Time Period	House Size in Sq. Ft.	# Parcels in 1000	Percent of Basin Total	# Samples in T. Survey	# Samples in F. Survey
Los Angeles County			1,415	62.9	755	126
1. OLD-Small	<1946	≤1000	129	5.7	69	12
2. OLD-Medium	<1946	1001-2000	185	8.2	99	16
3. OLD-Large	<1946	>2000	129	5.7	69	12
4. MED-Small	1946-1964	≤1000	113	5.0	60	10
5. MED-Medium	1946-1964	1001-2000	373	16.6	199	33
6. MED-Large	1946-1964	>2000	275	12.2	146	24
7. NEW-Small	1965-1986	≤2000	118	5.3	63	11
8. NEW-Large	1965-1986	>2000	93	4.1	50	8
Composite County			834	37.1	445	74
9. Orange	all year	all sizes	434	19.3	232	39
10. Riverside	all year	all sizes	160	7.1	85	14
11. San Bernardino	all year	all sizes	240	10.7	128	21
SoCAB Total			2,249	100	1200	200

SFRs in Los Angeles County were first classified into three time periods: OLD (pre-1946), MED (1946-1964), and NEW (post-1964). These periods were considered to coincide with times around which major changes in construction methods or materials took place.

The number of houses built during the MED period is by far the largest among the three periods (see Table 2-2). This is in agreement with our knowledge of the great housing boom in the fifties. It is apparent that the average size of pre-1946 SFRs is quite small (around 1200 square feet) whereas that of post-1964 SFRs is considerably larger (around 1900 square feet). Because of this trend toward larger houses in recent years, only two size categories are used for the post-1964 period: 2000 square feet or less, and over 2000 square feet.

Assessor records in Orange, Riverside and San Bernardino counties include neither "year built" nor "total livable feet". Therefore, all SFRs in each of these counties are grouped to form their own stratum. SFRs in Los Angeles County are grouped into 8 strata according to their age and size whereas those in Composite County were grouped into 3 strata according to their counties. In total, 11 strata are used for conducting both the telephone questionnaire survey of 1200 SFRs and the field survey of 200 SFRs.

2.2.2.2 NSFR Survey Design

Unlike SFR records in Los Angeles County, assessor records for NSFRs do not provide either age or size data for the NSFR parcels in any county. In addition, NSFRs are more variable than SFRs in size and types of construction materials. Therefore, to quantify materials associated with NSFRs, data gathering efforts must take precedence over analysis of existing data. However, conventional field and questionnaire survey methods do not seem likely to meet the increased data needs at an affordable cost.

In this study, a remote sensing technique called "airphoto analysis" has been applied to gather NSFR data at an affordable cost. "Airphoto analysis" is a subjective technique evolved through military applications. From photographs taken at various altitudes and angles, an experienced photo-analyst interprets the image of each designated object to estimate its physical dimensions, structural characteristics, and the types and amounts of materials used in their exterior surfaces.

Initially, VRC considered selecting 30 study sites of approximately 1 square kilometer each for airphoto analysis. However, 30 mapbook areas were used instead because exact counts of NSFRs by use category are available at mapbook level (through Mapbook-Stat file which has been generated from the assessor data bases). Since there are 2942 and 963 mapbooks, respectively, in Los Angeles and Composite Counties, an optimal selection of 30 mapbooks is not a simple task.

To ensure that NSFRs in the sample would be representative of the NSFR population in the SoCAB, the following criteria were considered in selecting 30 mapbooks:

1. The number of NSFR parcels in the sample should be as large as possible;
2. Use-type mix in the sample should resemble that of the NSFR population;
3. Selection of the sample should be made as objectively as possible; and
4. The sample so selected must be reasonable and practical for airphoto work.

Since parcel use categories in the Los Angeles County assessor data are more numerous and specific than those of the Composite County data, selections of mapbooks for Los Angeles and Composite counties were made separately: 20 mapbooks from Los Angeles County and 10 mapbooks from Composite County. However, the same methodology was applied to select mapbooks for the two sub-regions. The methodology used is rather complex and is described in detail in the interim report (Horie and Shrope 1987). In essence, a combination of objective and subjective selection methods was devised and employed. The objective selections were made using the following three performance indices to evaluate 6000 sets of 20 (for Los Angeles) or 10 (for Composite) randomly selected mapbooks:

$$PI1_j = SUM_k \mid P_{kj} - P_k \mid$$

$$PI2_j = SUM_k \mid P_{kj} - P_k \mid / P_k$$

$$PI3_j = SUM_k \mid P_{kj} - P_k \mid / (w_k n_{kj})$$

where P_k = proportion of parcels with the k-th use type,

P_{kj} = proportion of parcels with the k-th use type in the j-th set,

n_{kj} = the number of parcels with the k-th use type in the j-th set, and

w_k = the weight for the exterior surface of the k-th use type (1 for SMFR, 3 for LMFR and RCOND, 2 for SNR, 4 for LNR and 6 for MJR).

In determining the best set for the aerial photography mission, the following steps were taken:

STEP 1 - Selection of NSFR-Rich Mapbooks

Mapbooks in Los Angles County were ranked according to proportion of NSFR parcels in the mapbook, whereas those in Composite County were ranked according to the number of NSFR parcels in the mapbook. Then, only the highest-ranking mapbooks were considered for selection. This screening reduced the number of mapbooks for consideration from 2942 to 886 in Los Angeles County and from 963 to 262 in Composite County. (The reason for using different screening criteria for the two sub-regions is that while Los Angeles County mapbooks contain similar numbers of land parcels (about 1000), mapbooks in Composite County vary greatly in their numbers of land parcels.

STEP 2 - Evaluation of Sample Sets of 20 and 10 Mapbooks

A total of 6000 sets of 20 (or 10 for Composite County) mapbooks were generated using three different sampling methods: simple random sampling, stratified random sampling, and weight-stratified random sampling. Then, these sets were ranked in three different ways according to values of three different performance indices which are all designed to measure the closeness of use-type mix (excluding vacant and unknown-use parcels) in the set to that of the NSFR population in the subregion.

STEP 3 - Selection of Candidate Sets

The fifty top-ranked sets in each of the three performance indices were listed for all three sampling methods for closer scrutiny. (The top fifty sets selected by the simple random sampling method were considerably different from those by the stratified random sampling method whereas those by the second and third methods are rather similar to each other.) After visual scrutiny of these high-ranked sets, 18 sets which ranked consistently high in all indices and all sampling methods were selected as candidate sets for Los Angeles County. Similarly, 14 sets ranked consistently high were selected as candidate sets for Composite County.

STEP 4 - Final Determination of Study Sets for Los Angeles and Composite Counties

Noteworthy features of each mapbook included in the candidate sets were identified by examining aerial atlases of Los Angeles and Orange counties, Thomas Bros. maps with mapbook boundaries on them, and the numbers and use types of NSFR parcels. These identified features were then summarized for each candidate set as indicated in Table 2-3. (A similar table was prepared for Composite County as well.) For mapbooks in Riverside and San Bernardino counties for which an aerial atlas was unavailable, VRC staff physically visited the mapbook areas and evaluated their appropriateness as study sites. By reviewing the summary tables and other evaluation materials, the authors and two ARB scientists jointly selected Set 1549 to be a study set for Los Angeles County and Set 2533 to be a study set for Composite County.

In this final determination step, the following desirable features and undesirable features of each candidate set were subjectively evaluated:

Desirable Features

- The number of NSFR parcels is large.
- The number of LNR and MJR parcels is large.
- the set contains at least one major central business district (CBD).
- The set contains at least one regional commercial center.
- The set contains at least one major shopping center.

Undesirable

- The set contains a large institution like university and governmental complex.
- The set contains excessive open space like preservation area and undeveloped land area.
- The set contains a major transportation center like airport, rail head and harbor.

TABLE 2-3. SUMMARY FEATURES OF 18 CANDIDATE SETS FOR LOS ANGELES COUNTY

		Number of		Number of Mapbooks in/with							
Method/ Set Number	Rank by PI* 1-2-3	NSFRs	LNRs & MAJs	LA CBD	Other CBD	Regional Commercial Core	Shopping Center	Large Institu-tions	Excessive Open Space	Trans-portation Center	Restricted Airspace
METHOD 1: Simple Random Sampling											
1713	1-2-8	4417	1862	1	1	2	0	1	1	2	0
730	2-1-1	5539	2324	0	2	0	1	0	1	1	2
149	3-3-4	4732	1905	0	0	4	1	2	1	0	0
83	6-4-5	4133	1707	0	1	1	0	0	1	1	2
128	10-5-2	5310	2131	1	0	4	1	0	3	1	0
465	9-22-4	5286	2309	1	2	1	0	0	3	0	1
METHOD 2: Stratified Random Sampling											
1492	1-2-2	5263	2216	1	1	5	0	1	3	2	4
1817	2-1-1	5408	2146	0	2	2	0	0	1	0	0
1345	8-6-3	5419	2267	0	1	2	1	0	1	0	0
571	3-10-17	5372	2191	0	1	1	0	1	1	0	0
1272	14-4-8	5638	2257	0	3	1	0	1	3	0	1
710	5-15-12	5571	2303	0	1	2	0	1	2	2	1
METHOD 3: Weighted, Stratified Random Sampling											
187	1-1-1	6109	2541	0	0	3	1	0	1	2	3
1549**	2-2-8	5910	2533	0	1	1	0	0	0	0	0
1038	3-3-2	5619	2255	0	1	2	1	0	2	2	4
1124	5-9-5	6037	2570	0	1	4	1	1	0	0	1
1698	7-4-13	5972	2433	0	2	4	1	0	1	0	0
1634	12-20-3	5760	2348	0	0	4	1	0	1	1	1

* Performance indices

** This set was selected as the study set for Los Angeles County.

- The set extends over restricted airspace where airphoto flights can not be made.

Considering these desirable and undesirable features, all candidate sets except Set 1549 were eliminated. A similar screening method was applied to candidate sets for Composite County before deciding on mapbooks of Set 2533 as study sites.

Table 2-4 presents the numbers and types of land parcels in the study set and those in Los Angeles County. As seen from this table, the use-type mix in the study set is in excellent agreement with that of Los Angeles County.

It should also be noted that the proportion of NSFR use-types to the total number of land parcels in the set is considerably higher than that of Los Angeles County as a whole (42% vs. 18%). Since land parcels of vacant (VAC) and unknown use (UNK) were assumed to contain little material with economic significance, these parcel types were not taken into account in this survey design. However, materials in these parcels are taken into account both in actual survey and analysis phases.

Table 2-5 presents a similar land parcel summary for the study set for Composite County. In selecting this study set, minor use-types of mobile home (MH) and agriculture (AGR) as well as VAC and UNK were not considered. These use-types appear to be treated somewhat differently from one county to another. Here again, the use-type mix of the study set is in excellent agreement with that of entire Composite County.

TABLE 2-4. NUMBERS AND TYPES OF LAND PARCELS IN THE NSFR STUDY SET (1549) AND IN LOS ANGELES COUNTY

Mapbook	SMFR	LMFR	RCOND	SNR	LNR	MJR	Sub-total	Total Parcels
2321	57	114	6	15	99	5	296	632
2353	110	141	23	9	125	6	414	847
4016	72	106	11	13	109	8	319	536
4135	62	56	1	20	51	145	335	569
4252	90	172	8	7	61	6	344	1083
4337	57	65	19	14	133	4	292	744
5189	29	14	0	5	59	1	108	360
5283	71	4	0	10	94	2	181	646
5695	52	30	14	16	37	22	171	430
5746	63	48	13	43	156	13	336	692
5807	100	57	17	7	101	14	296	707
6102	4	0	0	52	235	3	294	359
6132	10	10	0	69	235	28	352	902
6251	45	48	0	24	62	5	184	716
7101	29	15	113	5	30	0	192	798
7271	40	61	0	29	15	144	289	385
8026	67	6	12	23	157	6	271	1007
8104	48	42	2	27	102	3	224	523
8139	74	83	7	51	215	33	463	647
8743	0	4	531	5	9	0	549	1357
Set Total	1080	1076	777	444	2085	448	5910	13958
Set Mix	.183	.182	.132	.075	.353	.076	1.00	
L.A. Total*	68	61	42	26	120	23	340	1885**
L.A. Mix	.200	.179	.124	.076	.353	.068	1.00	

* All values in thousands

** This total does not include 55,000 mobile homes which are not contained in the assessor data base.

TABLE 2-5. NUMBERS AND TYPES OF LAND PARCELS IN NSFR STUDY SET (2533) AND IN COMPOSITE COUNTY

County/Mapbook		MFR	RCOND	NR	Sub-total	Total Parcels
OR	22	112	18	218	348	1798
OR	70	139	65	266	470	3855
OR	84	179	173	313	665	3859
OR	129	125	113	67	305	1402
OR	133	157	8	140	305	2159
OR	298	80	109	150	339	859
RV	219	69	9	41	119	1106
SB	141	21	10	415	446	1586
SB	154	89	26	149	264	3156
SB	1011	26	225	362	613	1654
Set Total		997	756	2121	3874	21434
Set Mix		.257	.195	.548	1.00	
Orange*		262	203	387	852	5625
Riverside*		27	7	86	120	3060
San Bernardino*		57	47	259	363	3549
Composite Total*		346	257	732	1335	12234
Composite Mix		.259	.193	.548	1.00	

* All values in hundreds

2.2.2.3 Infrastructure Survey Design

Economically significant materials exposed to ambient air are found not only in SFRs and NSFRs but also in infrastructures such as highways, surface streets, power distribution networks, channelized waterways and railroads. Unlike materials associated with buildings, many of the materials found in infrastructures occur principally in repetitive standard forms and spaced at regular intervals, as in light standards along streets and highways.

Therefore, surveys for infrastructures focused on quantifying both infrastructure facilities by type and materials and material-bearing items associated with each type.

Basinwide miles of various types of roads are compiled in Table 2-6 using the statistics presented in the Highway Performance Monitoring System (HPMS) data summary (CALTRANS 1984). In the table, road miles in the SoCAB portion of each county are estimated by applying estimated urban and rural fractions to the reported road miles for that county.

For state highways, which are under CALTRANS' jurisdiction, no survey was necessary because reliable counts of material-bearing items (e.g., freeway signs and light poles) were available from the CALTRANS' District 7 in Los Angeles. However, counts of material-bearing items on surface streets are not readily available. Therefore, a special street survey was designed to obtain data on such material-bearing items for various types of surface streets. The numbers of survey routes selected for each road type are indicated in Table 2-6. The largest number of survey routes is needed for "urban local" streets for two reasons:

1. The road miles of "urban local" are by far the greatest among all road types; and
2. A survey route for "urban local" can be only 1 to 2 miles long in a continuous stretch while those for "arterials" and "collectors" can be 5 to 50 miles long.

As indicated the in the table, a total of 47 survey routes were selected for five different road types: 3 for principal arterial, 3 for minor arterial, 10 for urban collector, 30 for urban local, and 1 for rural collector. No survey was done for rural local because the number of material-bearing items to be found there was not expected to be significant. Although the number of survey routes differs from one road type to another, it was planned that the cumulative total miles of the survey routes would be in the range of 30 to 60 miles for each road type to be surveyed.

TABLE 2-6. TOTAL MILES OF ROAD BY TYPE IN EACH COUNTY AND NUMBER OF SELECTED SURVEY ROUTES FOR EACH ROAD TYPE (After CALTRANS 1983).

Road Type	Los Angeles[a]	Orange[b]	Riverside[c]	San Bernardino[d]	SoCAB
State Highway[e]	457	163	332	180	1132
Principal Arterial	2211 (2)	579 (1)	129	280	3199 (3)
Minor Arterial	1929 (1)	606 (1)	267	507 (1)	3309 (3)
Urban Collector	2015 (7)	347 (1)	278 (1)	410 (1)	3050 (10)
Urban Local	10516 (10)	3274 (9)	1443 (5)	1984 (6)	17217 (30)
Rural Collector[f]	139	72	649 (1)	155	1015 (1)
Rural Local	225	231	1156	299	1911
Total	17492 (20)	5272 (12)	4250 (7)	3815 (8)	30829 (47)

Note: Numerals in parenthesis indicate the number of selected survey routes

a Include 100% of urban road and 10% of rural road.

b Include 100% of urban road and 100% of rural road.

c Include 90% of urban road and 50% of rural road.

d Include 90% of urban road and 10% of rural road.

e Include urban interstate and other freeway, and rural interstate, principal arterial and minor arterial.

f Include major collector and minor collector.

For other infrastructures such as power distribution networks, railroads, and channelized waterways, no systematic survey was conducted. Instead, the numbers of material-bearing items in these infrastructures were estimated by indirect methods such as contacting a data source organization and reading an appropriate map showing locations of such infrastructures.

2.2.3 MEASUREMENT SYSTEM

To develop a reliable inventory of materials-in-place requires accurate inventories of facilities by type and of the types and amounts of materials in those facilities. Using the tax assessor data bases, as previously explained, VRC determined the sizes and characteristics of the statistical populations of SFRs and NSFRs and, to a lesser degree, of state highways and surface streets. In the NAPAP study (Merry and LaPotin 1985), these facility populations were estimated from survey results whereas, in the previous ARB study (Murray et al 1985), a surrogate population of housing units was used instead.

There are so many types of materials and material-bearing items in various facilities that no single method of measurement can be used effectively in quantifying materials-in-place under all situations. Therefore, a cogent measurement system was needed for effectively classifying and quantifying materials found in surveyed facilities. Since none of the earlier studies produced such a system, VRC developed a completely new measurement system.

Full specification of materials-in-place requires the following determinations:

(i) material type

(ii) surface finish

(iii) dimensions of exposed surfaces

(iv) building component in which the materials are found

(v) facility in which the materials are found

To make such determinations for even a single window may require over 100 measurements of dimensions of numerous elements such as window casings, frames, panes, sealants, screens, screen frames, splines, security bars, awning shades, and awning supports. It was impractical to make such detailed measurements repetitively for each element of all surveyed facilities. Instead, this study devised a measurement system that enabled us to determine types and amounts of materials-in-place with satisfactory accuracy in an efficient manner.

Under this system, materials-in-place are first classified according to the types of material-bearing elements or items:

> Primary Element - For primary elements such as basic sections of wall, roof, ground cover and fence, and gross surfaces of window, door, chimney, etc., both the dimensions and material types are determined either by on-site measurements (for SFRs) or remote sensing techniques (for NSFRs).
>
> Secondary Element - For secondary elements such as gutters, window frames, window panes, window screens, window screen frames, security door frames, etc., the quantities of identified materials are calculated from the dimensions of corresponding primary elements (e.g., window frame and pane from the dimension of window casing) according to a formula which VRC derived from test cases.
>
> Enumeration Item - Enumeration items such as air conditioning units, antennas, sky lights, light poles, street signs, etc., are first classified into proper categories and then tallied. The types and amounts of materials contained in a given category of enumeration items are computed using the standard material factors for that category, which VRC derived from test cases.

For primary elements, both identification of material-finishes and actual measurements of all dimensions are implemented rigorously. We spurn any guessing in favor of actual identification of material type and actual measurements of all key dimensions of each element either by direct inspection or by examining a photographic image. In both the NAPAP study and the ARB study, the field work involved some degree of guesswork, primarily because the field surveyors never entered the property being surveyed. This procedure can leave many materials undetected, especially in backyards.

In this study, all surveyed SFRs were observed by field surveyors who physically inspected both front and rear aspects of the properties after obtaining permission from the owners or residents. From a pilot study, it became evident that any guessing regarding unseen sides of the property introduced unacceptable errors in identifying the types of material present and in quantifying the areas of their exposed surfaces.

For secondary elements such as those found in windows, our efforts were focused on identifying the types of materials used, rather than taking detailed masurements of the minute dimensions of all the substructures. The reasons for omitting detailed measurements of such secondary elements are twofold:

1. Avoiding routine, repetitive measurements of many identical substructure elements allows field surveyors to focus their efforts on recording key dimensions of buildings and other essential features of the property and on identifying material types present in both primary and secondary elements; and
2. The field survey of a target house can thus be completed in an expedient manner, normally less than 2 hours.

The second reason was important for this study because particularly in a large metropolitan area like the SoCAB, property owners do not like to leave their houses while strangers are taking measurements.

Simple enumeration, without on-site measurement, of similar or identical items such as air conditioning units and light poles also speeds up a material inventory survey. More important, many enumeration items can not be measured accurately in a routine survey activity. For example, antennas on rooftops or light poles can not be easily accessed for detailed measurements during a casual visit. For enumeration items, VRC measured in detail for a few test cases (usually 2 to 5) and considered the findings to be typical for observed but unmeasured items of the same type.

3.0 SINGLE FAMILY RESIDENCES

3.1 GENERAL

Among all use-types considered, SFRs are by far the most numerous, accounting for over two thirds of all land parcels in the SoCAB (see Table 2-1). Therefore, to develop a reliable inventory of materials-in-place in the basin, it is crucial to account accurately for all materials associated with the SFR population. To ensure an accurate accounting, VRC conducted two surveys:

1. Telephone Questionnaire Survey of 1200 randomly selected SFRs; and
2. Field Survey of 200 SFRs which were selected from those surveyed in 1.

The purpose of the field survey was to make an accurate account of all types of materials present in surveyed SFR parcels, while the primary purpose of the telephone questionnaire survey was to obtain a larger, more representative sample of the SFR population.

Section 3.2 of this report discusses the questionnaire survey, while Section 3.3 describes all phases of the field survey: protocol development, survey execution, and data reduction. Section 3.4 discusses analyses of the survey-generated data and presents predictive equations derived for materials associated with the SFR population.

3.2 TELEPHONE QUESTIONNAIRE SURVEY

For the first time ever in material inventory studies, VRC has used a telephone questionnaire survey as a means of gathering data on materials present in SFR parcels. By taking advantage of the greater flexibility and cost effectiveness of the telephone questionnaire approach, VRC has surveyed 1200 houses selected randomly from tax assessor records in four counties composing the SoCAB. All earlier studies depended on field surveys of only a few hundred houses in any one study area. Considering the great diversity in ages and configurations of existing buildings, a sample of this magnitude appears to be necessary to ensure that the proportions of houses in the sample having detached garages, second stories, fences, and other noteworthy features are indeed representative of the SFR population.

3.2.1 SAMPLE SELECTION FOR QUESTIONNAIRE SURVEY

From the SFR Mini-Universe, which is a ten percent sample of the basinwide SFR population, an initial list of 10,530 SFR owners was generated according to a stratified random sampling method. Then, using appropriate telephone directories, telephone numbers were identified for 3823 of these households, from the names and street addresses. Telephone numbers of the remaining households could not be readily identified mainly because they were unlisted. A smaller fraction of identified listings were unsuitable for the survey because of name-only listings, corporate owners, and owners who reside outside of the study region.

A question was raised as to whether these unlisted phone numbers had introduced any significant bias into the sample. To examine this potential bias due to unlisted phone numbers, distributions of SFR sizes in each of three periods (pre-1946, 1946-1964, post-1964) were computed separately for all houses and for houses with identified phone numbers in Los Angeles County, for which "year built" and "total livable space" data are available.

Table 3-1 presents comparisons of SFR size distributions in each period for houses with listed phone number versus all houses. Frequency density values of houses with phones and all houses in each size range are, in general, in reasonable agreement; differences between them appear to be within a normal sample variation. Therefore, it was judged that use of SFRs with listed phone numbers would not cause any significant bias in the sample.

In the table, it should also be noted that medians for houses with listed phone numbers occurred in the same size ranges as those for all houses in three periods. These coincidental occurrences of the two medians in the same size range may provide further evidence that the use of SFRs with listed phone numbers would not cause a significant bias in the survey sample. As mentioned earlier, a trend toward larger houses in recent years is exemplified in the shift of the medians from 1001-1500 square feet in Period 1, to 1251-1500 square feet in Period 2, and to 1751-2000 square feet in Period 3.

TABLE 3-1. COMPARISON OF SFR SIZE DISTRIBUTIONS FOR HOUSES WITH LISTED PHONE NUMBERS VERSUS ALL HOUSES FOR THE SoCAB

Square Footage	Pre-1946		1946-1964		1965-1986	
	w/Phone	All Houses	w/Phone	All Houses	w/Phone	All Houses
750 or Less	.047	.073	.019	.029	.003	.004
751 to 1000	.171	.218	.081	.120	.011	.016
1001 to 1250	.279	.254	.227	.261	.046	.055
1251 to 1500	.146	.164	.247	.229	.127	.146
1501 to 1750	.116	.096	.172	.159	.165	.177
1751 to 2000	.069	.064	.095	.082	.154	.156
2001 to 2500	.085	.059	.097	.074	.281	.234
2501 to 3000	.034	.030	.040	.028	.124	.122
3001 to 4000	.040	.028	.021	.014	.078	.071
4001 or More	.014	.014	.002	.004	.011	.016
Sample Size	656	2135	1323	3669	370	1016

---median for houses with listed phone numbers

——median for all houses

Table 3-2 provides the numbers of SFRs initially sampled, houses with listed phone numbers and target number of complete interviews for each of the eleven strata. The target numbers of complete interviews are calculated in proportion to each stratum's share of the basinwide SFR population. Los Angeles County accounts for 63 percent of the SFR population and Composite County for 37 percent. Among the eight age-size strata in Los Angeles County, MED-medium cell (i.e., medium sized SFRs of Period 2) gets the largest sample allocation, 296 or 24.7 percent of the target total. Among the three strata in Composite County, Orange County cell gets the largest allocation, 232 or 19.3 percent.

TABLE 3-2. ALLOCATION OF SURVEY HOUSES TO LOS ANGELES AND COMPOSITE COUNTY STRATA FOR THE TELEPHONE QUESTIONNAIRE SURVEY

County/Stratum	Yr-Built	Sq. Ft.	# SFRs Initially Sampled	# Houses w/Phone	Percent of Total	Target No. of Interviews
Los Angeles County						
1. OLD-Small	Pre-1946	≤1000	621	143	5.7	69
2. OLD-Medium	Pre-1946	1001-1500	892	279	8.2	99
3. OLD-Large	Pre-1946	>1500	622	234	5.7	69
4. MED-Small	1946-1964	≤1000	546	132	5.0	60
5. MED-Medium	1946-1964	1001-1500	1797	627	16.6	199
6. MED-Large	1946-1964	>1500	1326	564	12.2	146
7. NEW-Small	1965-1986	≤2000	566	187	5.3	63
8. NEW-Large	1965-1986	>2000	450	183	4.1	50
Los Angeles Total			6820	2349	62.9	755
Composite County						
9. Orange	all year	all sizes	1930	817	19.3	232
10. Riverside	all year	all sizes	710	293	7.1	85
11. San Bernardino	all year	all sizes	1070	364	10.7	128
Composite Total			3710	1474	37.1	445
Grand Total			10530	3823	100.0%	1200

3.2.2 QUESTIONNAIRE DESIGN AND TESTING

To elicit factual information regarding exterior materials at selected home sites, VRC designed a questionnaire to be used in the telephone survey. Wording and phrasing of the questions were carefully considered and reconsidered so as to avoid alarming respondents and to reassure them as to the legitimacy of the telephone contact, thereby encouraging them to answer candidly. Subjects covered by the questionnaire were the following:

- General Information, including questions on livable square footage, year built, number of stories and type of garage;
- Roof, including questions for main house and detached garage on roof material, roof slope, eaves, rain gutters and downspouts, the number and types of chimneys and other roof-attachments such as TV antennas, skylights and evaporative coolers;
- Windows, including questions for each side of the house on the number and type of windows, window screens, security bars, awnings, and window frame materials;
- Doors, including questions for each side of the house on the number and type of doors, door materials and screen doors;
- Walls, including questions for house and garage on main wall materials on all sides except the front, and on the garage door;
- Front wall, including questions on the types of materials and their proportions in the front wall;
- Fence, including questions on the types, materials, and dimensions of fences;
- Other items, such as carport, patios, walkways, pools, spas, and pool decks and presence or absence of outdoor accessories such as sheds, gazebos, satellite dishes, and air conditioning units.

Since telephone interviewing is more art than science, only highly experienced telephone interviewers were allowed to conduct the interviews. Ms. Eve Fielder, Director of the UCLA's Survey Research Center, thoroughly briefed each interviewer as to the objectives and scope of the interviews. Having a good understanding of the purpose of the questions being asked, the interviewer could readily judge the reasonableness of each response and engage in clarifying dialogue to resolve awkward or unsound responses, thereby enhancing the quality of the interview.

VRC tested the survey questionnaire by conducting pilot surveys of single-family residences in Los Angeles County. Results of the first round revealed the following:

1. Of the 40 attempts:

   14 interviews were completed;

   10 refused (3 involved female interviewers while 7 were male);

   1 interviewee terminated mid-way;

   7 had either disconnected telephones or wrong addresses; and 8 non-connects.

2. Male interviewers were less successful than their female counterparts. It seems likely that the male projects a more threatening image as perceived by persons responding to detailed questions about their homes.

3. A few unsuitable question sequences and a few ambiguous questions were identified.

4. On balance, the questionnaire and protocols appeared to work well.

In a second round, only female interviewers participated and a revised questionnaire was used. Results of this round were:

1. Of the 34 attempts:

   14 interviews were completed;

   2 refused;

   0 terminated;

   1 wrong address; and

   17 non-connects (as before, limited attempts).

2. Respondents seemed sensitive to direct questions dealing with security bars on windows (question sequence later revised);

3. Interviewers experienced some difficulties with the sequence of questions dealing with target materials on the front of the house (question sequence later revised).

As a further check, four sites with completed interviews were selected for "ground-truthing". This involved a VRC staff member going to the site with the questionnaire to check the validity of the interview. Except for the 3rd problem (with the sequence of questions) in each case, the interview was found to be gathering the intended information.

Based on the information gained in this second round, VRC again revised the questionnaire. The final version of the questionnaire is provided in Appendix A.

3.2.3 SURVEY EXECUTION

About a half dozen interviewers were recruited for this survey, mostly from those associated with the UCLA's Survey Research Center. The interviewers were instructed as to the purpose of the survey and provided with a list of answers to anticipated questions and concerns which might be raised by interviewees. Although these interviewers were all veterans with five to ten years of experience, they raised numerous questions and concerns about unexpected cases for which their common sense judgment did not provide a ready solution.

Concerns raised by interviewees were answered directly by VRC staff members whereas those of interviewers were handled by the survey coordinator. The concern most frequently raised by interviewees was about authenticity of the survey, that is, the real purpose of this study. Many residents obviously had difficulty accepting that detailed questions on their houses were indeed related to air pollution problems. By telephone and by mail, VRC staff explained to them how air pollution can cause deterioration of paint and other exposed materials.

The questions which caused most difficulty to interviewers turned out to be those on fences and ground cover materials. Nearly all interviewers complained about their difficulties in dealing with unusual fence set-ups and material combinations. On the other hand, many interviewees had difficulty in providing accurate answers regarding square-footage of walkways, driveways, pools, spas and decks, etc.

Table 3-3 presents a summary of telephone interview results. The overall completion rate was 57 percent. The 18-percent refusal rate seems reasonable, considering the complexity of the questionnaire and the unease of residents on being asked about their homes. The remaining non-responses(25 percent) were caused by a variety of reasons including non-working numbers and inability to contact, even after five attempts.

TABLE 3-3. SUMMARY RESULTS OF TELEPHONE INTERVIEWING

County/ Stratum	Target No. Interviews	# Attempted Interviews (A)	# Successful Interviews (B)	# Refusals (C)	# Uncon- nected	Response Rate (B/A)	Refusal Rate (C/A)
<u>Los Angeles County</u>							
1. OLD-Small	69	141	74	21	46	0.52	0.15
2. OLD-Medium	99	162	99	18	45	0.61	0.11
3. OLD-Large	69	104	69	18	17	0.66	0.17
4. MED-Small	60	96	61	11	24	0.64	0.11
5. MED-Medium	199	357	199	74	84	0.56	0.21
6. MED-Large	146	237	145	48	44	0.61	0.20
7. NEW-Small	63	134	62	13	59	0.46	0.10
8. NEW-Large	50	90	50	19	21	0.56	0.21
Sub-Total	755	1321	759	222	340	0.57	0.17
<u>Composite County</u>							
9. Orange	232	399	225	92	82	0.56	0.23
10. Riverside	85	156	84	16	56	0.54	0.10
11. San Berndn	128	219	132	42	45	0.60	0.19
Sub-Total	445	774	441	150	183	0.57	0.19
Grand Total	1200	2095	1200	372	523	0.57	0.18

The number of completed interviews in each of the 11 strata is generally in good agreement with the target number assigned to that stratum although small differences between the two numbers occurred in some strata (e.g., 5 too many in OLD-Small and 7 too few in Orange County). These discrepancies were due to three causes:

1. In some cases, interviews were reassigned to other interviewers to allow attempts at other times of day and other days;
2. Different interviewers targeting separate parts of the list for a given stratum did not always know when the target number was reached; and
3. In some cases, questionnaires initially judged complete were found not to be so.

Results of the questionnaire survey are discussed in Section 3.4 together with those of the field survey.

3.3 FIELD SURVEY

From among the 1200 houses in the completed questionnaire survey, 200 were selected as a subsample for the field survey, according to a stratified random sampling method. The distribution of the 200 samples over the eleven strata is the same as that for the questionnaire survey (see Table 2-2 for exact sample allocations). VRC considered these as final sampling points and thus did not relinquish any of them unless there was absolutely no practical way to obtain from them permission to enter for field measurements. Locations of these 200 houses are shown in Figure 3-1.

Prior to undertaking a field survey, all field surveyors reviewed the completed questionnaires for the target houses and transcribed all pertinent data from these houses onto a specially designed coding sheet. This review and transcription exercise produced a long list of material types that would be encountered in the field survey. To familiarize themselves with the complex typology of materials, all field surveyors were assigned to test the procedures and their skills at a few houses which were selected from homes of the staff members, surveyors and their acquaintances.

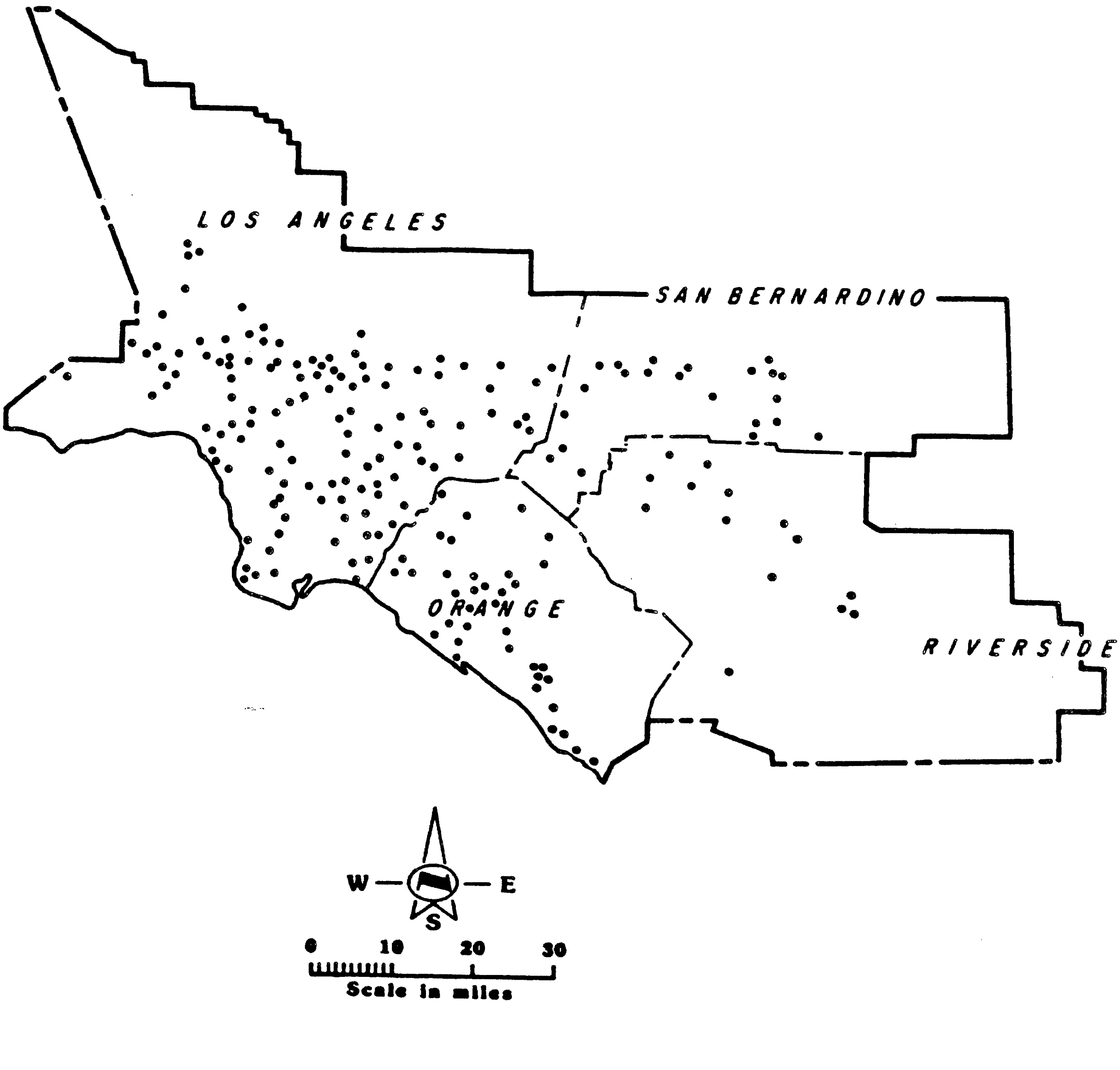

Figure 3-1. Locations of 200 Houses Examined in the Field Survey.

3.3.1 DEVELOPMENT OF SURVEY PROTOCOL

To conduct a field survey on materials-in-place in selected SFR parcels, VRC recruited four college students (2 from UCLA and 2 from Stanford University). These students were all in natural science majors and junior year, to ensure that they would be available throughout the survey period (i.e., June through September 1988) and that they were adequately skilled in geometrical calculations.

To familiarize them with types of materials and structures present in SFRs, all students were first assigned to work on the completed questionnaires from the questionnaire survey. Together, the students and VRC staff developed a long list of materials used in roofs, walls, windows, doors, fences and ground covers. There were surprisingly many materials which were reported in the questionnaires but were not readily classifiable in generic terms.

In particular, there were many unfamiliar materials reported as roofing materials. For example, steel, concrete, aluminum, "decratile", etc. were reported in the questionnaires. To determine what generic materials they represented, VRC staff visited some of the houses reporting those materials and then contacted roofing contractors and hardware stores to inquire about. Through this exercise, the students and staff came to realize how many new roofing materials there were and how easily they could be misclassified. For example, a new roofing material made of asphalt composite on aluminum base can easily be misjudged to be "terra cotta" or "Spanish tile". Another is a concrete shingle which simulates wood shingle. To a lesser degree, similar situations exist with new materials used for window screens, garage doors, regular and screen doors, and wall surfaces.

From the findings regarding the numerous materials used in roofs, walls, doors, etc., VRC developed a list of generic materials and finishes used for various components of SFRs and NSFRs, as shown in Appendix B. To ensure that this list would be workable under various SFR situations, it was left

* An optical range finder is a device to measure distance to the object of interest by optical focusing. The accuracy is said to be 1 to 3 percent at distances from 25 feet to 100 feet. This was verified by comparing readings by the range finder with tape measurements of the distances. A survey protractor is a hand-held device with a bubble level to measure a zenith or azimuth angle of the object of interest. This device was used to measure the slopes of roofs.

open-ended at the start of the field survey, with space to insert additional materials and finishes.

Two survey teams of two students each were formed to conduct a field survey on 200 selected SFRs. Each team, accompanied by a VRC staff member, was sent to two houses, as a training exercise to acquire basic survey skills and develop survey protocols. Physical measurements were made for every detail of the houses using the following tools: yardstick, tape measure, optical range finder*, survey protractor, camera and field worksheet.

The field worksheet shown in Appendix C was evolved from experience gained from field measurements of the training houses. After a few trials and false starts, we settled on a simple hand-drawn house plan with detailed dimensions of house components and notes about materials present there, to record all basic information concerning the house. Details about individual components and accessories were recorded in loosely formatted tables, which were designed separately for roof accessories, windows, doors, wall accessories and other accessories. The last page of the worksheet was used to draw the parcel boundaries, fences and any other noteworthy features except for the house itself. These procedures were formalized in "Instructions for Field Worksheet" (see Appendix D) and were followed by every surveyor.

As an alternative method, measurements based on photographs of the house were also attempted. However, it quickly became evident that photo-interpretation by untrained persons led to frequent misclassification or gross omissions of materials in ground covers, minor structures and unseen sides of the house. In addition, reviewing photo-prints turned out to be a clumsy method for making quantitative measurements of minute details of the house. In this study, photographs of all surveyed houses were taken as confirmatory evidence that the right houses were surveyed and that materials were correctly identified by field surveyors.

As discussed in Section 2.2.3 - Measurement System, field measurements were made differently for:

1. Quantitative items requiring identification of materials and measurements of all relevant dimensions;

2. Deductive items requiring identification of materials and measurements of perimeters only; and

3. Enumeration items requiring classification only.

Examples of Type 1 items are materials found in roofs, walls, windows, doors, minor structures and ground covers. Examples of Type 2 items are latticeworks of windows, window screens, screen doors, and metal trims on eaves and doors. Examples of Type 3 items are air conditioning units, antennas, light fixtures, solar panels and skylights.

In calculating surface areas from original measurements, it was decided that exposed surface area would be determined for all identified materials except screens and chainlink fences. For the latter, apparent surface area (e.g., single side area of a screen or a chainlink in stretched condition) was computed. Thus, the exposed surface of the frame material of a window screen was computed for both sides of the frame whereas a single side of the screen area was computed for the screen material. We believed that replacement costs of screens and chainlinks would be more readily relatable to area in square feet than would linear feet of metal or fiberglass wire or square feet of the wire surfaces.

3.3.2 FIELD SURVEY EXECUTION

Unlike the previous ARB study (Murray, et al 1985) and the NAPAP study (Merry and LaPotin 1985), all field measurements in this study were made by physically entering both the front and back yards of every target house. (However, we did not climb the roof or visit second story of any house.) To enter the property for measurements, VRC survey teams had to obtain permission from the owner or other resident of every target house.

To increase the chance of obtaining permission, a cogent survey procedure was developed and observed throughout the field survey:

> <u>Letter Notice</u> About a week in advance of any actual visits to target houses, an ARB letter was mailed to all affected residents. This letter expressed ARB's appreciation of their cooperation with the questionnaire survey and solicits similar cooperation for that forth coming field survey. It also explained that the surveys would wear photo-identification cards and carry copies of the letter.

Entry Permission   Upon arrival at a target house, surveyors were required to seek permission to enter, by explaining the purpose of their visit and what measurements they want to make. If no one was at the house, they were required to revisit the house twice before giving up. Should permission be denied either by refusal or by continued absence of the resident, the surveyors were then allowed to select and survey a substitute house in the immediate neighborhood, which was in all structural aspects equivalent to the target house. If no such house was found, a replacement residence was drawn randomly from among questionnaire-surveyed houses in the same stratum.

Field Measurement   Upon entering the property, one surveyor measured all key dimensions of house components, minor structures, if any, ground covers and fences while the other sketched the configuration of the house and minor structures and recorded key dimensions and materials identified. For individual components, all noteworthy items found were recorded by material, finish type, X-Y dimensions, and the numbers of the items (see Appendix C).

Photo-Identification   Upon completion of the survey, surveyors expressed their thanks to the resident. Before leaving the site, they photographed the house. Upon development of the photoprint, they recorded the house I.D. number, the survey team number, and the date of the survey on the back of the print.

After two to three weeks of training in June 1988, two survey teams of two students each initiated the field survey in July. For one survey trip, each team was assigned about five target houses in a compact geographical area. If, at any house, the resident was absent, that house was to be revisited at a later time on the same day or on another day. As the surveyors learned how to develop a quick rapport with the residents of target houses, their rate of success in obtaining permission to enter their target houses increased, reducing the need of substituting equivalent houses or having new target houses assigned. Overall, field measurements were conducted for 176 target houses and 24 substitute houses.

Table 3-4 summarizes results of the field visit outcomes. In total, field visits were made to 259 target houses for which we had completed questionnaires. Of these attempts, successful field measurements were performed for 176 target houses and 24 substituted houses. The completion rate for target houses alone was 68 percent. With the substituted houses, the overall completion rate is raised to 77 percent. Among the factors which helped achieve these high completion rates, we may identify the following:

1. Residents visited by the surveyors had been previously interviewed in the telephone questionnaire survey;
2. The letter of notification was mailed just a few days in advance of the visits;
3. Surveyors were well trained to dress and behave properly; and
4. No target house was dropped until at least three unfruitful visits had been made.

TABLE 3-4. SUMMARY RESULTS OF FIELD SURVEY

County/ Stratum	Target No. of Completes	# Attempted Houses (A)	# Completes on Target House (B)	# Completes on Substitute House (C)	Completion Rate (B/A)	Overall Rate (B+C)/A
Los Angeles County						
1. OLD-Small	12	23	11	1	.478	.522
2. OLD-Medium	16	21	16	1	.762	.810
3. OLD-large	12	17	12	0	.706	.706
4. MED-Small	10	12	9	1	.750	.833
5. MED-Medium	33	40	27	6	.675	.825
6. MED-Large	24	32	23	1	.718	.750
7. NEW-Small	11	14	8	2	.571	.714
8. NEW-Large	8	8	6	2	.750	1.00
Sub-Total	126	167	112	14	.670	.754
Composite County						
9. Orange	39	46	35	3	.761	.826
10. Riverside	14	20	10	4	.500	.700
11. San Berndn	21	26	19	3	.731	.846
Sub-Total	74	92	64	10	.696	.804
Grand Total	200	259	176	24	.680	.772

3.3.3 DATA REDUCTION AND ENCODING

While quantities recorded in field worksheets are item names, material types, finishes and basic dimensions of individual items, data required by the objectives of this project are material-finish surfaces in specified components such as roof, basic wall and window. For most measured items, this transformation from raw data in the field worksheets to material-finish surfaces were done in a straightforward manner. However, some measured items were found to require rather elaborate data reduction schemes.

For example, there are three different types of eaves: Smooth (S) - those without any exposed beams underneath; Open (O) - those with open, exposed beams underneath; and Boxed (B) - those with undersides completely boxed in. Since it is rather redundant to measure the width and height of exposed beams for every case, surveyors used a cryptic note like 1,0/^/O in the field worksheet (see Appendix C). This means that the eave is 1 foot wide, without facing, rising (or sloped), and with open beams. Conventions used to compute the exposed surfaces are:

Soffit = Length x Width x 2

Facing = Length x Facing With x 2 x Roof Factor

where the roof factor is given by a reciprocal of cosine of the roof angle.

Conventions like the above were derived and used for calculating exposed surfaces of gutters, downspouts, fences, doors, door screens, windows and window screens as well. These conventions were derived from detailed measurements of specific houses, those of hardware-store specimens, and experience gained through the field survey. All conventions used to reduce field worksheet data to material-finish surfaces are compiled and presented in Appendix E. In the appendix, definitions of terms used are also given.

To make a concise, yet comprehensive presentation of all calculated material surfaces in a single record, a cogent data coding system was devised. This data coding system has the following features:

Hierarchical - In every record, data are organized in a hierarchical order: first, parcel summary data; then component summary data; and finally individual material-finish data.

Comprehensive - Every house is fully described by summary data and detailed material-finish data for all recognized components of the house: roof, roof features, roof accessories, ..., ground cover area, ground accessories, and fences.

Built-in Redundancy - For every component, the total area and total number of material-finish combinations are given, and must be matched with the consequent data of individual material-finish combinations found in that component.

The third feature provided an effective means of detecting and correcting all encoding errors and data inconsistencies. In the second feature, VRC also introduced the concepts of "primary elements" and "secondary elements" for windows and doors. Primary elements were considered to be essential for integrity of the house whereas secondary elements are not. For example, panes and casings are essential parts of a window and thus are included in primary window elements. On the other hand, screens and awnings emplaced on the window are optional and thus were included in secondary window elements. Similar distinctions were made for items associated with doors.

A full data coding sheet is given in Appendix F. This coding sheet is organized as follows:

Parcel Summary - including parcel I.D., reported and measured livable space, building footprint, number of buildings, and number of stories;

Component Summary - including total exposed area of and total number of material-finish combinations found in the component; and

Material-Finish - including either material-finish and its exposed area or accessory type, size and the number, depending upon whether the item is quantitative or enumerative type.

The types of components listed in the coding sheet are: roof, roof feature (e.g., chimney and gutter), roof accessory (e.g., solar panel and TV antenna), basic wall, primary window, secondary window (e.g., screens, security bar and awning), primary door, secondary door (e.g., screen door and security bar), wall attachment (e.g., downspouts and attached water heater casing), soffit (eaves and underneath surface), minor structure (e.g., patio and shed), ground cover (e.g., walkway and garage pavement), ground accessory (e.g., climatic unit and pool heater), and fence.

It should be noted that the number of buildings is given in the parcel summary whereas material-finishes in different buildings (e.g., detached garage and main house) are entered collectively to relevant components such as roof, basic wall, primary window and primary door. In this way, a single record covers all material-finish combinations found in the parcel.

3.3.4 RELIABILITY OF FIELD SURVEY DATA

Several material inventory field surveys have been conducted elsewhere (e.g., Merry and LaPotin 1985, Murray et al 1985). However, none of these field surveys addressed uncertainties involved in such surveys other than sampling errors. Since accurate identification and quantification of a great variety of material-finishes in field can never be a simple matter, VRC conducted a special case study to test the reliability of in-field determinations of material types and material-finish surfaces.

Two survey teams, "Red" and "Blue" were sent at different times to three test houses: House 1 - single story with detached garage, House 2 - single story attached house; and House 3 - two story with detached garage. Each team first conducted in-field measurements of the three test houses independent of the other team. Then both teams jointly surveyed the three houses to obtain the most accurate measurements of material-finishes in those houses. In this joint measurement, members of the two teams reviewed their previous findings and discussed their differences in detail, arguing pro and con on procedures, interpretations, classification, etc. Subsequently, they jointly re-evaluated the disputed items endeavoring to achieve agreement on each item.

By the data reduction and coding procedures discussed in the preceding section, raw measurement data for the three houses were all reduced to material-finish surfaces. Results for Test Houses 1, 2 and 3 are summarized in Tables 3-5, 3-6 and 3-7 respectively. These tables list all material finishes identified by Red and Blue teams and their surface areas in square

TABLE 3-5. TEST HOUSE 1 - SINGLE STORY WITH DETACHED GARAGE

Category	Red	Blue	Diff *	Actual	Dif Red **	Dif Blue
Building Footprint	1926	1787	7	1982	3	10
Building Primary	5701	5955	4	6510	12	9
Parcel Total	9848	10729	8	11141	12	4
Asphalt Shingle	2531	2336	8	2653	5	12
Painted Wood	1191	1785	33	1533	22	16
Painted Aluminum	9	0	100	9	0	100
Painted Stucco	1943	1990	2	2065	6	4
Bare Galv. Steel	20	8	60	19	5	58
Bare Aluminum	62	47	24	65	5	28
Bare Brick	76	64	16	98	22	35
Glass	231	231	0	231	0	0
Stained Wood	20	21	5	21	5	0
Aluminum Screen	19	18	5	19	0	5
Fiberglass Screen	87	85	2	86	1	1
Painted Iron	26	29	10	28	7	4
Bare Concrete	2137	1989	14	2376	10	16
Bare Block	1020	1467	30	1419	28	3
Painted Galv. Steel	3	27	89	27	89	0
Tar	162	225	28	168	4	34
Chain Link Fence	32	45	29	44	27	2
Bare Wood	162	210	23	168	4	25
Painted Steel	0	9	100	5	100	44
Unspecified Stone	117	143	18	107	9	34
# of Mat'l-Finish	19	19	0	20	5	5

* 100 X ABS(Red - Blue) / Larger of Red or Blue
** 100 X ABS(Red - Actual) / Actual

TABLE 3-6. TEST HOUSE 2 - SINGLE STORY WITH ATTACHED GARAGE

Category	Red	Blue	Diff *	Actual	Dif Red **	Dif Blue
Building Footprint	1734	1793	3	2335	26	23
Building Primary	5344	5690	6	5866	9	3
Parcel Total	12017	12079	1	13187	9	8
Tar	2242	2320	3	2565	13	10
Painted Wood	2125	1891	11	2032	5	7
Painted Stucco	1805	1910	5	2082	13	8
Bare Brick	826	459	44	791	4	42
Glass	159	155	3	159	0	3
Bare Aluminum	51	52	2	51	0	2
Fiberglass Screen	94	86	9	94	0	9
Painted Iron	15	14	7	12	25	17
Stained Wood	485	0	100	0		
Canvas	572	524	8	660	13	21
Bare Concrete	2101	2700	22	2860	27	6
I/O Carpet	240	240	0	240	0	0
Bare Block	1023	1090	6	924	11	18
Chain Link Fence	279	280	0	293	5	4
Painted Galv. Steel	0	0	0	14	100	
Bare Galv. Steel	0	8	100	0		
Bare Wood	0	350	100	410	100	15
# Mat'l-Finish	14	15	7	15	7	0

* 100 X ABS(Red - Blue) / Larger of Red or Blue
** 100 X ABS(Red - Actual) / Actual

TABLE 3-7. TEST HOUSE 3 - TWO STORY WITH DETACHED GARAGE

Category	Red	Blue	Diff *	Actual	Dif Red **	Dif Blue
Building Footprint	1714	1703	1	1968	13	13
Building Primary	6355	6612	4	6625	4	0
Parcel Total	13481	15030	10	14910	10	1
Wood Shingle	1418	1464	3	1626	13	10
Asphalt Roll	0	60	100	64	100	6
Bare Galv. Steel	94	106	11	119	21	11
Painted Galv. Steel	133	150	11	86	55	74
Painted Wood	2060	2518	18	1223	68	106
Painted Stucco	3355	3611	7	3715	10	3
Glass	480	556	14	552	13	1
Bare Aluminum	66	55	17	71	7	23
Fiberglass Screen	506	485	4	477	6	2
Bare Brick	468	220	53	543	14	59
Painted Steel	61	65	6	63	3	3
Painted Aluminum	187	616	70	595	69	4
Chain Link Fence	205	400	49	45	356	789
Bare Asphalt	1605	1630	2	1832	12	11
Bare Wood	442	1216	64	1034	57	18
Bare Block	494	718	31	763	35	6
Bare Concrete	1240	1160	6	1397	11	17
Tile	467	0	100	0		
Bare Stone	200	0	100	0		
Tar	0	0	0	695	100	100
# Mat'l-Finish	18	17	6	17	6	0

* 100 X ABS(Red - Blue) / Larger of Red or Blue
** 100 X ABS(Red - Actual) / Actual

feet. In addition to individual material-finish data, parcel totals are indicated by building footprint, building primary (excluding secondary elements in windows and doors), parcel total (including all material-bearing items in the parcel except for enumeration items), and the number of material-finish combinations. Results of the joint measurement are listed in a column designated as "Actual".

Results of this test study indicate that percent differences between the two teams are less than 10 percent in parcel summary variables, around 20 percent in material-finishes over 500 square feet, and up to 100 percent in those less than 500 square feet. Major causes of these differences appear to be misclassification of certain items into similar material-finish categories, and omission of items in small quantity such as painted steel found in a fuse box.

3.4 MATERIALS IN SFR PARCELS

This section discusses results of the telephone questionnaire survey and the field survey. For the latter, all survey results were further reduced to exposed surface areas by material-finish combinations. In the first subsection, Section 3.4.1, results of the telephone questionnaire survey are discussed and compared with those of the field survey. Quantitative estimates of material-finish combinations in individual sampling strata and in aggregated strata are discussed in the second subsection, whereas predictive equations to extrapolate the survey results to the basinwide SFR population and its sub-populations are discussed in the third subsection, Section 3.4.3.

3.4.1 COMPARISON OF FIELD AND QUESTIONNAIRE SURVEY RESULTS

With a large sample of 1200 houses, the telephone questionnaire survey would yield more robust estimates of proportions of houses with certain materials or features than the field survey, whose sample size is only 200. On the other hand, the questionnaire survey is subject to potential response errors, which we have been able to measure using data compiled in the field survey, during visits to some of the surveyed houses.

By comparing questionnaire responses and on-site identification of material-bearing items for individual houses, we classified questionnaire questions into three categories.

Reliable Those questions which yielded responses in good agreement with on-site identifications of the subject items or material-finishes asked;

Marginal Those with responses in fair agreement with on-site identifications of the subject items or material-finishes; and

Unreliable Those with responses in poor agreement with on-site identifications of the subject items or material-finishes.

To classify the questions in this manner, we chose the most reliable subset of 151 houses from those surveyed by the questionnaire and field surveys. As previously explained, 24 of the houses surveyed were substituted houses (i.e., not belonging to the set initially started). Of the 176 target houses surveyed, for 25 houses on-site measurements were limited to the fronts and sides only because their residents declined to permit entry to their backyards. For the remaining 151 (= 200 - 24 - 25) houses, surveyors at the site filled out the same questionnaire as used in the questionnaire survey.

By comparing questionnaire responses and surveyor's answers to each questionnaire item for the 151 houses, the reliability of questionnaire responses to various items was rated as follows:

Reliable if the responses and the surveyor's answers agreed in more than 85 percent of all cases;

Marginal if the responses and the answers agreed in 60 percent to 85 percent of all cases; and

Unreliable if the responses and the answers agreed in less than 60 percent of all cases.

Table 3-8 lists questionnaire items whose reliability ratings are judged to be "reliable", "marginal" or "unreliable". Those rated "reliable" include: general house features such as the number of stories, garage type and size, roof slope and the number of chimneys; presence or absence of accessories such as those on roof (e.g., TV antenna), window (e.g., awning) door (e.g., screen), and ground (e.g., pool and walkway);and basic building materials such as those used for garages, chimneys, walkways, driveways and carports.

Basic materials that elicit responses not reliable are those used for main house walls, roofs, gutters and downspouts, windows, window frames, patios, front walls and fences. In particular, responses for front walls and fences were rated "unreliable". Other items rated "unreliable" are gutter coverage (around roof line), numbers of downspouts, windows and doors, window size, door type, fence type, and areas of front wall materials.

TABLE 3-8. RATING RESPONSE RELIABILITIES FOR QUESTIONNAIRE ITEMS

Response Reliability Percent Correct)	Questionnaire Items
Reliable (85-100)	# stories, garage type and size, roof slope, # chimneys, chimney material, P* roof accessories, P window accessories, P screen door, garage wall material, P carport, carport material, P walkway, walkway material, driveway material, P pool or spa, P door accessories
Marginal (60-85)	roof material, eave width, P gutter and downspout, gutter & downspout material, window frame material, basic wall material, proportion of windows and doors in front wall, patio material
Unreliable (60)	gutter coverage, # downspouts, # windows, window size, # doors, door type, front wall material by area, fence type, fence material

* P indicates presence of the stated element.

This grouping of questionnaire items according to the reliability scale seems to indicate a limitation of the questionnaire survey: often, people can correctly answer questions about obvious features of their houses but not about details. In view of this limitation, we used only those items whose responses were considered trustworthy for characterizing the SFR population.

Table 3-9 summarizes characteristics of building configurations for houses in each of the three periods (OLD, MED and NEW) and in Los Angeles and Composite counties. The proportion of two-story houses is considerably higher in NEW (post-1964) than OLD (pre-1946) and MED (1946-1964). Similarly, the proportion of attached garages is the highest in NEW, followed by MED and then by OLD. As to roof slope, sloped houses dominate in all three periods. As to chimneys, houses without chimneys dropped dramatically from 42 percent in OLD to 35 percent in MED and to 8 percent in NEW.

TABLE 3-9. CONFIGURATION CHARACTERISTICS OF THE 1200 QUESTIONNAIRE-SURVEYED HOUSES (All values in fractions of designated sample size).

Questionnaire Items	OLD (242)	MED (405)	NEW (112)	L.A. (759)	COMP (441)	SoCAB (1200)
Number of Stories						
1 - story house	.864	.953	.580	.870	.810	.847
2 - story house	.136	.047	.420	.130	.190	.153
Garage Type						
Attached	.195	.574	.911	.503	.823	.621
Detached	.730	.396	.062	.453	.136	.336
No Garage	.075	.030	.027	.044	.041	.043
House Roof Slope						
Sloped	.735	.869	.884	.828	.930	.866
Flat	.116	.030	.071	.064	.025	.049
Both	.149	.101	.045	.108	.045	.085
Number of Chimneys						
None	.422	.348	.080	.332	.177	.275
One	.570	.612	.875	.631	.778	.685
Two	.008	.040	.045	.037	.045	.040

Since the population growth in the SoCAB has been faster in Composite County than in Los Angeles County in the last 10 to 20 years, houses in Composite County are, in general, newer than those in Los Angeles County. Because of this, Composite County has higher proportions of two-story houses and houses with attached garages and chimneys as compared to Los Angeles County.

Table 3-10 provides a summary of predominant materials found in various components of the 1200 surveyed houses. As anticipated, this table exhibits marked changes over time in materials used for roofs and window frames. As to roofing material, asphalt composite shingles dominated in OLD and MED periods whereas in NEW, wood shingles became a dominant material, followed by terra cotta which increased markedly as compared to the earlier periods. Wood window frame, which was dominant in OLD and MED periods, was almost entirely replaced by aluminum frame in NEW period.

On the other hand, materials used for basic walls, walkways and driveways remained nearly the same throughout the three periods, except for wood in walls which was more common in OLD than in MED and NEW periods. Another noticeable change is a steady decrease in houses without walkways or driveways.

Composite County, whose houses are newer than those in Los Angeles County, tended to have higher proportions of houses with wood shingle and terra cotta roofs, and with aluminum window frames.

The limited reliability of data from the questionnaire survey suggests that a material inventory should be based chiefly on data gathered in the field survey. However, the sample size in the field survey was much smaller than in the questionnaire survey, raising the question whether the field survey sample adequately represents the SFR population. To answer this question, Tables 3-11 and 3-12 show the proportions of houses with particular features or materials as found in the field survey and the questionnaire survey at basinwide and age strata levels, respectively.

TABLE 3-10. PREDOMINANT MATERIALS FOUND IN THE 1200 QUESTIONNAIRE-SURVEYED HOUSES (All values in fractions of designated sample size).

Component/ Material-Finish	OLD (242)	MED (405)	NEW (112)	L.A. (759)	COMP (441)	SoCAB (1200)
Roof Material						
Asphalt Roofing	.603	.563	.161	.516	.385	.468
Wood shingle	.120	.175	.455	.199	.397	.272
Tar	.103	.170	.107	.140	.066	.113
Terra cotta	.099	.044	.196	.084	.122	.098
Other	.075	.048	.081	.061	.030	.049
Basic Wall Material						
Stucco	.756	.941	.929	.880	.873	.878
Wood	.198	.052	.071	.101	.084	.095
Other	.046	.007	.000	.019	.043	.027
Basic Wall Finish						
Painted/stained	.967	.970	.964	.966	.848	.923
Bare	.033	.030	.036	.034	.152	.077
Window Frame Material						
Aluminum	.174	.311	.732	.329	.651	.448
Wood	.789	.630	.205	.618	.293	.498
Other	.037	.059	.063	.053	.056	.054
Walkway Material						
Not present	.574	.346	.241	.403	.358	.387
Concrete	.335	.560	.696	.509	.578	.534
Other	.091	.094	.063	.088	.064	.079
Driveway Material						
Not present	.120	.047	.000	.063	.052	.059
Concrete	.735	.563	.812	.655	.744	.688
Asphalt	.116	.373	.170	.261	.184	.232
Other	.029	.017	.018	.021	.020	.021

Table 3-11 compares house proportions found in the field survey vs. those in the questionnaire survey at basin- and county-wide levels. Proportions of houses with two stories, detached garages, and particular roof and wall materials in the field survey sample are essentially the same as those in the questionnaire survey sample. Although there are noticeable differences in incidence of sloping roofs between the two survey samples, these differences appear to be well within sampling errors.

Table 3-12 shows the same comparisons as Table 3-11 but at a lower level, namely in each of the three periods (except for Composite County whose data could not be disaggregated by time periods). Even at this level, house proportions in the two survey samples are generally in fairly good agreement. (Agreement should not be expected to be as good in cases like the comparison for new houses, where the field survey sample was quite small -- only 18.)

Based on the comparisons discussed above, it can be said that the field survey sample is adequately representative of the SFR population at basin- and county-wide levels. However, at time period level, its representativeness is marginal, requiring some caution in using the field survey data at that level.

TABLE 3-11. COMPARISON OF HOUSE MIXES DEPICTED BY THE QUESTIONNAIRE SURVEY AND THE FIELD SURVEY AT COUNTY- AND BASIN-WIDE LEVEL (All values in fractions of designated sample size).

Questionnaire Items	Questionnaire Survey Los Angeles (759)	COMP (441)	SoCAB (1200)	Field Survey Los Angeles (124)	COMP (74)	SoCAB (198)*
Number of Stories						
1 - story house	.87	.81	.85	.83	.85	.84
2 - story house	.13	.19	.15	.17	.15	.16
Garage Type						
Attached	.50	.82	.62	.50	.86	.63
Detached	.45	.14	.34	.46	.14	.34
No garage	.05	.04	.04	.04	.00	.03
House Roof Slope						
Sloped	.83	.93	.87	.80	.96	.86
Flat	.06	.03	.05	.04	.00	.03
Both	.11	.04	.08	.16	.04	.11
Roof Material						
Asphalt roofing	.52	.38	.47	.51	.38	.47
Wood shingle	.20	.40	.27	.17	.39	.25
Tar	.14	.07	.11	.17	.07	.13
Terra cotta	.08	.12	.10	.09	.15	.11
Other	.06	.03	.05	.06	.01	.04
Basic Wall Material						
Stucco	.88	.87	.88	.85	.90	.87
Wood	.10	.08	.09	.13	.07	.11
Other	.02	.04	.03	.02	.03	.02

* Although all 200 houses were surveyed in the field survey, two houses, which had undergone major remodeling after they were interviewed in the questionnaire survey, were deleted from the original sample of 200. These two houses belonged to Stratum 1 (OLD-Small) and Stratum 4 (MED-Small).

TABLE 3-12. COMPARISON OF HOUSE MIXES DEPICTED BY THE QUESTIONNAIRE SURVEY AND THE FIELD SURVEY AT AGE STRATA LEVEL (All values in fractions of designated sample size).

Questionnaire Items	Questionnaire Survey OLD (242)	MED (405)	NEW (112)	COMP (441)	Field Survey OLD (40)	MED (66)	NEW (18)	COMP (74)
Number of Stories								
1 - story house	.86	.95	.58	.81	.82	.92	.50	.85
2 - story house	.14	.05	.42	.19	.18	.08	.50	.15
Garage Type								
Attached	.20	.57	.91	.82	.15	.60	.89	.86
Detached	.73	.40	.06	.14	.80	.35	.11	.14
No garage	.07	.03	.03	.04	.05	.05	.00	.00
House Roof Slope								
Sloped	.73	.87	.88	.93	.75	.83	.78	.96
Flat	.12	.03	.07	.03	.05	.02	.11	.00
Both	.15	.10	.05	.04	.20	.15	.11	.04
Roof Material								
Asphalt roofing	.60	.56	.16	.38	.72	.42	.39	.38
Wood shingle	.12	.18	.45	.40	.03	.23	.28	.39
Tar	.10	.17	.11	.07	.03	.29	.05	.07
Terra cotta	.10	.04	.20	.12	.15	.03	.11	.01
Other	.08	.05	.08	.03	.07	.03	.11	.01
Basic Wall Material								
Stucco	.75	.94	.93	.87	.70	.92	.89	.90
Wood	.20	.05	.07	.09	.27	.06	.11	.07
Other	.05	.01	.00	.04	.03	.02	.00	.03

3.4.2 MATERIALS-IN-PLACE FOR FIELD-SURVEYED HOUSES

Although detailed data on materials found in the 198 houses in the field survey are all recorded in the field-survey data base (the data format is described in Appendix F), a useful summary of the data is not simple because there are multiple levels of many variables: subregions (L.A. and Composite); SFR strata by age and size; house components such as roof, wall, window and door; item types such as basic, attachment, accessory, and enumeration; material types such as stucco, wood, asphalt composite, and steel; and finish types such as bare, painted and galvanized.

Because of the complexity of the data, only salient features of material-finishes in the surveyed houses are discussed in this section. Detailed computer-generated statistics have been submitted to ARB for review and use by professionals who may be interested in such data.

Exposed material surfaces of a house and associated items in a SFR parcel are classified into the following simple categories:

- Roof
- Roof Feature (chimney, eave facing and gutter)
- Soffit
- Basic Wall
- Primary Window
- Secondary Window (window screen, awning, and security bar)
- Primary Door
- Secondary Door (screen door and security door)
- Wall Attachment (downspout, attached shed, water heater box)
- Ground Cover (driveway, walkway, planter box, deck, and any other thing that is neither soil nor grass)
- Minor Structure (patio, detached shed, gazebo, and carport)
- Fence

and three aggregated categories:

- <u>Building Primary</u> including roof, soffit, basic wall, primary window and primary door;
- <u>Building Secondary</u> including roof feature, secondary window, secondary door, and wall attachment;
- <u>Ground Component</u> including ground cover, minor structure, and fence.

Mean exposed surface areas of these components among the surveyed houses are summarized in Table 3-13. The two most dominant components are roof and basic wall, accounting nearly a half of the total exposed surface area of a SFR parcel which ranges from 8753 square feet in OLD to 9752 square feet in NEW. Among the three aggregated components, building primary account for about 60 percent of the parcel total, followed by ground component (≅ 35 percent) and building primary (≅ 5 percent). These proportions remain about the same for the three periods (OLD, MED and NEW) and for Los Angeles and Composite Counties.

TABLE 3-13. MEAN EXPOSED SURFACE AREAS BY CATEGORY IN SFR STRATA (All values in square feet per house)

Component Name	OLD (40)	MED (66)	NEW (18)	L.A. (124)	COMP (74)	SoCAB (198)
Roof	2181	2344	2324	2289	2434	2343
Roof Feature*	241	260	335	265	284	272
Soffit*	489	518	726	539	811	641
Basic Wall	2220	1917	2124	2045	1905	1993
Wall Attachment*	36	28	10	28	15	23
Primary Window	323	279	239	288	223	263
Secondary Window*	136	99	95	111	83	100
Primary Door	189	239	286	230	233	231
Secondary Door*	60	62	50	59	51	56
Minor Structure*	382	342	448	370	430	393
Ground Cover	1488	1446	1666	1491	1255	1403
Fence*	1009	1348	1449	1258	1600	1386
Building Primary	5402	5297	5699	5391	5606	5471
Building Secondary	472	449	490	463	433	451
Ground Component	2879	3136	3563	3119	3285	3182
Parcel Total	8753	8882	9752	8973	9324	9104
Measured						
Livable Mean	1487	1448	1890	1525	1552	1535
Space s.d.	918	540	484	691	452	611

* Note that these components were not found in some houses. The numbers of houses missing these components were: 3 in roof feature, 1 in soffit, 61 in wall attachment, 16 in secondary window, 22 in secondary door, 69 in minor structure, and 1 in fence.

Basinwide, the mean livable space (excluding garage area) of a house is 1535 ft^2 whereas the mean exposed surface areas of building primary, ground component and parcel total are, respectively, 5471, 3182 and 9104 ft^2. These exposed surface areas are considerably greater than those reported elsewhere (Murray et al 1985, Host 1985). Thus, while Table 3-13 shows total building primary areas averaging from about 5300 to 5700 square foot per house, the previous ARB study (Murray et al 1985) estimated the total exposed surface area to be about 1300 ft^2 for houses in low income areas of the SoCAB, 2000 ft^2 for medium income areas, and 2500 ft^2 for high income areas. The NAPAP study (Host 1985) estimated it to be 2823 ft^2 for Portland (Maine), 3479 ft^2 for New Haven, 2735 ft^2 for Pittsburgh, and 3247 ft^2 for Cincinnati.

The small values reported in these two studies appear to be caused primarily by exclusion of roof materials (except for those used for gutters) in their calculations. The present study has compiled exposed surfaces of all economically significant materials, including roof materials as well as those on ground within the property boundary.

Table 3-14 provides detailed accounts of exposed surface areas by material-finish for building primary, i.e., the sum of roof, soffit, basic wall, primary window and primary door elements. In all six SFR strata examined, the two preponderant materials are wood and stucco. Painted and bare stucco account, respectively, for about 25 percent and 5 percent of the total exposed surface in SoCAB. The sum of painted and stained wood accounts for 20 percent of the total exposed surface while wood shingle (bare) accounts for another 12 percent. Material mixes among the three periods and between Los Angeles and Composite, in general, remained about the same except for particular materials such as aluminum and wood shingles, which were more abundant in NEW and MED than in OLD.

Table 3-15 shows the same material-finish areas as Table 3-14 but for parcel total, which includes building secondary and ground components as well as building primary. As compared to material areas for building primary, those for parcel total showed considerably more earthy materials (such as block, brick and concrete), used for ground cover, and metallic materials (such as aluminum, steel, iron and chain link), and wood and fiberglass, used for building secondary. Total exposed surface areas range from 8753 ft^2 in OLD to 9752 ft^2 in NEW, with SoCAB average 9104 ft^2. These exposed areas are approximately 3500 ft^2 greater than those of building primary whose basin average is 5471 ft^2.

TABLE 3-14. MEAN EXPOSED SURFACE AREAS BY MATERIAL-FINISH FOR BUILDING PRIMARY IN SIX SFR STRATA (All values in square feet per house).

	Material-Finish	OLD (40)	MED (66)	NEW (18)	L.A. (124)	COMP (74)	SoCAB (198)
111	Block - Bare	-	3	44	8	6	7
112	Block - Painted	5	3	-	3	1	2
121	Brick - Bare	138	53	59	81	56	72
122	Brick - Painted	6	28	10	18	4	13
131	Concrete - Bare	1	1	-	1	4	2
132	Concrete - Painted	1	1	2	1	1	1
141	Stucco - Bare	232	128	255	180	437	276
142	Stucco - Painted	1296	1482	1514	1427	1165	1329
151	Tile - Bare	-	2	-	1	-	1
152	Tile - Painted	-	-	-	-	-	-
161	Terra Cotta - Bare	221	-	406	130	256	177
181	Cement Shingle - Bare	128	-	-	41	125	73
391	Unspecified Stone - Bare	9	9	13	10	11	10
411	Aluminum - Bare	26	35	71	38	44	40
412	Aluminum - Painted	26	51	28	40	15	30
421	Anodized Aluminum - Bare	-	1	1	1	3	2
431	Aluminum Screen - Bare	-	-	-	-	-	-
441	Steel - Bare	-	1	-	1	1	1
442	Steel - Painted	8	5	-	5	2	4
451	Galvanized Steel - Bare	-	-	-	-	-	-
452	Galvanized Steel - Painted	1	-	6	1	-	1
461	Iron - Bare	-	-	-	-	-	-
462	Iron - Painted	2	-	2	1	-	1
471	Chain Link - Bare	-	-	-	-	-	-
501	Chicken Wire - Bare	-	-	-	-	-	-
591	Unspecified Metal - Bare	-	-	-	-	-	-
592	Unspecified Metal - Painted	-	-	-	-	-	-
611	Nylon - Bare	-	-	-	-	-	-
711	Wood - Bare	39	6	10	25	20	
712	Wood - Painted	1103	887	1093	987	1118	1036
715	Wood - Stained	26	11	18	17	62	34
721	Wood Shingle - Bare	-	688	676	464	956	648
722	Wood Shingle - Painted	63	-	-	20	-	13
725	Wood Shingle - Stained	4	-	-	2	-	1
731	Plastic - Bare	-	-	-	-	-	-
741	Vinyl (hard) - Bare	-	-	11	2	-	1
742	Vinyl (hard) - Painted	-	-	-	-	-	-
751	Tar - Bare	172	415	199	305	210	270
761	Asphalt - Bare	-	-	-	-	-	-
771	Asphalt Roofing - Bare	1655	1256	1031	1353	889	1179
781	Glass - Bare	232	231	250	235	216	228
791	Fiberglass - Bare	3	1	-	1	-	1
801	Fiberglass Screen - Bare	-	1	-	1	1	1
811	I/O Carpet - Bare	6	-	-	2	-	1
	Total Area	5402	5297	5699	5391	5606	5471

Note: Due to round-off errors, the elements may not equal the total.

TABLE 3-15. MEAN EXPOSED SURFACE AREAS BY MATERIAL-FINISH FOR PARCEL TOTAL IN SIX SFR STRATA (All values in square feet per house).

	Material-Finish	OLD (40)	MED (66)	NEW (18)	L.A. (124)	COMP (74)	SoCAB (198)
111	Block - Bare	314	624	791	559	536	550
112	Block - Painted	43	22	45	32	1	21
121	Brick - Bare	416	198	201	268	179	235
122	Brick - painted	10	32	17	22	7	16
131	Concrete - Bare	1028	897	1388	1011	962	993
132	Concrete - Painted	88	78	21	74	36	59
141	Stucco - Bare	239	132	263	186	497	302
142	Stucco - Painted	1338	1496	1528	1451	1181	1350
151	Tile - Bare	-	4	7	3	4	4
152	Tile - Painted	-	-	9	1	-	1
161	Terra Cotta - Bare	229	-	406	133	255	178
181	Cement Shingle - Bare	129	-	-	41	125	73
391	Unspecified Stone - Bare	39	34	41	37	23	32
411	Aluminum - Bare	78	70	118	80	67	76
412	Aluminum - Painted	130	174	84	147	133	142
421	Anodized Aluminum - Bare	2	3	3	3	6	4
431	Aluminum Screen - Bare	43	47	13	40	20	33
441	Steel - Bare	1	2	-	2	7	4
442	Steel - Painted	19	12	15	14	7	12
451	Galvanized Steel - Bare	36	35	14	32	22	28
452	Galvanized Steel - Painted	25	28	17	26	15	22
461	Iron - Bare	-	-	-	-	-	-
462	Iron - Painted	20	22	22	22	14	19
471	Chain Link - Bare	260	250	364	270	325	290
501	Chicken Wire - Bare	6	11	8	9	44	22
591	Unspecified Metal - Bare	1	5	4	4	1	3
592	Unspecified Metal - Painted	5	5	5	5	2	4
611	Nylon - Bare	1	-	-	-	-	-
711	Wood - Bare	335	314	240	310	610	422
712	Wood - Painted	1492	1264	1605	1388	1667	1492
715	Wood - Stained	75	28	101	54	77	63
721	Wood Shingle - Bare	-	688	676	466	957	649
722	Wood Shingle - Painted	64	-	-	21	-	13
725	Wood Shingle - Stained	4	-	-	2	-	1
731	Plastic - Bare	5	-	-	2	-	1
741	Vinyl (hard) - Bare	-	2	11	3	-	2
742	Vinyl (hard) - Painted	-	-	-	-	-	-
751	Tar - Bare	172	426	199	311	212	274
761	Asphalt - Bare	46	318	60	194	98	157
771	Asphalt Roofing - Bare	1688	1284	1068	1384	903	1204
781	Glass - Bare	234	231	254	236	217	229
791	Fiberglass - Bare	32	39	17	33	16	27
801	Fiberglass Screen - Bare	94	79	98	87	87	86
811	I/O Carpet - Bare	8	10	40	13	7	12
	Total Area	8753	8882	9752	8973	9324	9104

Note: Due to round-off errors, the sum of elements may not equal the total.

Mean exposed areas of individual material-finishes may have very different statistical reliability because of the different numbers of non-zero cases included in the means. Table 3-16 shows the number of data points from which, for each material-finish, an estimate of the parcel total exposed surface area is derived (see Table 3-15). Although all 198 houses were surveyed, many houses turned out not to have particular material-finishes. Indeed, only painted wood and bare glass were found in all the houses: all other material-finish combinations were absent from at least some houses. For example, cement shingle was found in only four of the 198 houses, whereas bare aluminum was found in 185. Yet, their mean exposed surface areas were nearly the same, 73 ft^2 for cement shingle versus 76 ft^2 for bare aluminum. The mean for the latter would be a much more reliable estimate* than that for the former because of the larger number of data points (185 as compared to 4).

Table 3-17 provides a breakdown of exposed surface areas by component as well as material-finish. It indicates that materials associated with roofs, walls, windows and fences are distinctly different. For windows, glass, painted wood and bare aluminum are the preponderant materials whereas for roof, asphalt shingle, wood shingle, tar and terra cotta are preponderant. For walls, painted stucco is preponderant by far, followed by painted wood and bare stucco. For fence, bare block, bare and painted wood, and chain link are the preponderant materials.

Table 3-18 shows mean areas of painted surfaces by material. For all three periods (OLD, MED, and NEW), stucco and wood are by far the preponderant painted materials. It is noteworthy that painted metals such as aluminum and steel are nearly as abundant as painted earthy materials such as block, brick and concrete. In terms of the ratio of total painted surface to total exposed surface, houses in OLD have a slightly higher ratio than those in MED and NEW (37% vs. 35%). Similarly, houses in Los Angeles County have a higher proportion of painted surface than those in Composite County (36% vs. 33%).

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* To illustrate this point, imagine that a house lacking the above two materials were not included in the survey sample. Then, the mean for cement shingle might decrease drastically, say to 45 ft^2, while the mean for bare aluminum would remain practically unchanged.

TABLE 3-16. NUMBER OF HOUSES WITH THE STATED MATERIAL-FINISH IN PARCEL TOTAL BY SFR STRATA.

Material-Finish		OLD (40)	MED (66)	NEW (18)	L.A. (124)	COMP (74)	SoCAB (198)
111	Block - Bare	29	55	16	100	52	152
112	Block - Painted	6	8	2	16	2	18
121	Brick - Bare	22	55	12	89	49	138
122	Brick Painted	3	8	4	15	3	18
131	Concrete - Bare	40	63	17	120	69	189
132	Concrete - Painted	18	14	3	35	9	44
141	Stucco - Bare	6	6	3	15	20	35
142	Stucco - Painted	30	60	15	105	56	161
151	Tile - Bare	-	5	1	6	2	8
152	Tile - Painted	-	-	1	1	-	1
161	Terra Cotta - Bare	6	-	4	10	9	19
181	Cement Shingle - Bare	1	-	-	1	3	4
391	Unspecified Stone - Bare	7	9	4	20	8	28
411	Aluminum - Bare	37	63	18	118	67	185
412	Aluminum - Painted	28	55	10	93	52	145
421	Anodized Aluminum - Bare	5	8	2	15	15	30
431	Aluminum Screen - Bare	24	42	7	73	28	101
441	Steel - Bare	2	5	-	7	5	12
442	Steel - Painted	15	21	5	41	14	55
451	Galvanized Steel - Bare	17	34	6	57	26	83
452	Galvanized Steel - Painted	17	32	5	54	19	73
461	Iron - Bare	-	1	-	1	-	1
462	Iron - Painted	15	16	6	37	17	54
471	Chain Link - Bare	24	31	9	64	23	87
501	Chicken Wire - Bare	2	4	1	7	4	11
591	Unspecified Metal - Bare	1	3	1	5	3	8
592	Unspecified Metal - Painted	3	4	2	9	5	14
611	Nylon - Bare	1	-	-	1	-	1
711	Wood - Bare	26	43	8	77	55	132
712	Wood - Painted	40	66	18	124	74	198
715	Wood - Stained	21	24	6	51	26	77
721	Wood Shingle - Bare	-	17	5	22	28	50
722	Wood Shingle - Painted	1	-	-	1	-	1
725	Wood Shingle - Stained	1	-	-	1	-	1
731	Plastic - Bare	1	1	-	2	-	2
741	Vinyl (hard) - Bare	-	2	1	1	1	2
742	Vinyl (hard) - Painted	-	1	-	1	1	2
751	Tar - Bare	6	15	2	23	8	31
761	Asphalt - Bare	2	29	3	34	14	48
771	Asphalt Roofing - Bare	32	53	10	85	34	119
781	Glass - Bare	40	66	18	124	74	198
791	Fiberglass - Bare	4	14	2	20	5	25
801	Fiberglass Screen - Bare	35	57	18	110	70	180
811	I/O Carpet - Bare	2	3	4	9	4	13

TABLE 3-17. MEAN EXPOSED SURFACE AREAS BY MATERIAL-FINISH IN HOUSE COMPONENTS FOR SoCAB (All values in square feet per house).

Material-Finish		Roof	Basic Wall	Primary Window	Fence	Building Primary	Parcel Total
111	Block - Bare	-	7	-	525	7	550
112	Block - Painted	-	2	-	15	2	21
121	Brick - Bare	-	72	-	15	72	235
122	Brick - Painted	-	13	-	1	13	16
131	Concrete - Bare	-	2	-	1	2	993
132	Concrete - Painted	-	1	-	4	1	59
141	Stucco - Bare	-	266	-	18	276	302
142	Stucco - Painted	-	1247	-	8	1329	1350
151	Tile - Bare	-	1	-	-	1	4
152	Tile - Painted	-	-	-	-	-	1
161	Terra Cotta - Bare	176	1	-	-	177	178
181	Cement Shingle - Bare	73	-	-	-	73	73
391	Unspecified Stone - Bare	-	9	-	4	10	42
411	Aluminum - Bare	-	-	23	-	40	76
412	Aluminum - Painted	1	10	3	1	30	142
421	Anodized Aluminum - Bare	-	-	1	-	2	4
431	Aluminum Screen - Bare	-	-	-	-	-	33
441	Steel - Bare	-	-	1	-	1	4
442	Steel - Painted	-	1	3	1	4	12
451	Galvanized Steel - Bare	-	-	-	1	-	28
452	Galvanized Steel - Painted	-	-	-	1	1	22
461	Iron - Bare	-	-	-	-	-	-
462	Iron - Painted	-	1	-	15	1	19
471	Chain Link - Bare	-	-	-	290	-	290
501	Chicken Wire - Bare	-	-	-	19	-	22
591	Unspecified Metal - Bare	-	-	-	-	-	3
592	Unspecified Metal - Painted	-	-	-	-	-	4
611	Nylon - Bare	-	-	-	-	-	-
711	Wood - Bare	-	4	-	345	20	422
712	Wood - Painted	-	323	52	107	1036	1492
715	Wood - Stained	-	16	-	8	34	63
721	Wood Shingle - Bare	647	2	-	-	648	649
722	Wood Shingle - Painted	-	12	-	-	13	13
725	Wood Shingle - Stained	-	1	-	-	1	1
731	Plastic - Bare	-	-	-	-	-	1
741	Vinyl (hard) - Bare	-	1	-	-	1	2
742	Vinyl (hard) - Painted	-	-	-	-	-	-
751	Tar - Bare	267	-	-	-	270	274
761	Asphalt - Bare	-	-	-	-	-	157
771	Asphalt Roofing - Bare	1179	-	-	-	1179	1204
781	Glass - Bare	-	-	180	-	228	229
791	Fiberglass - Bare	-	-	-	3	1	27
801	Fiberglass Screen - Bare	-	-	-	-	1	86
811	I/O Carpet - Bare	2	-	-	-	1	12
	Component Total	2343	1993	263	1386	5471	9104

Note: Due to round-off errors, the sum of elements may not equal the total.

TABLE 3-18. MEAN PAINTED SURFACES BY MATERIAL FOR PARCEL TOTAL IN SFR STRATA. (All values in square feet per house).

Material*	OLD (40)	MED (66)	NEW (18)	L.A. (124)	COMP (74)	SoCAB (198)
Block	43	22	45	32	1	21
Brick	10	32	17	22	7	16
Concrete	88	78	21	74	36	59
Stucco	1388	1496	1528	1451	1181	1350
Tile	-	-	9	1	-	1
Aluminum	130	174	84	147	133	142
Steel	19	12	15	14	7	12
Galvanized Steel	25	28	17	26	15	22
Iron	20	22	22	22	14	19
Unspecified Metal	5	5	5	5	2	4
Wood	1492	1264	1605	1388	1667	1492
Wood Shingle	64	-	-	21	-	13
Painted Total	3248	3133	3368	3203	3063	3151
Parcel Total	8753	8882	9752	8973	9324	9104

* Only painted materials are listed. Materials never painted are: terra cotta, cement shingle, unspecified stone, anodized aluminum, aluminum screen, chain link, chicken wire, nylon, plastic, vinyl, asphalt, asphalt shingle, glass, fiberglass, fiberglass screen, and I/O carpet.

3.4.3 BASINWIDE INVENTORY OF MATERIALS ASSOCIATED WITH SFRs

Since this study used land parcels as a basic survey unit, the basinwide SFR population has been accurately computed using tax assessor records of the four counties composing the SoCAB. This provides a much firmer basis for scaling up the survey results to the entire SoCAB than the previous ARB study (Murray et al 1985) and the NAPAP study (Merry and LaPotin 1985). The ARB used census tracts for housing as a basic survey unit. However, the number of housing units does not indicate the number of buildings or land parcels, in view of the prevalence of multi-dwelling units such as duplexes, triplexes, apartments, and condominiums. The NAPAP study used a fixed-size land area (called a "footprint") as a basic sampling unit. Therefore, the survey results obtained by sampling the footprints had to be used to estimate the number of buildings as well as the types and amounts of materials-in-place.

In this study, basin totals of exposed surface areas of any material-finishes are estimated as a product of the number of SFR parcels in the SoCAB and the mean surface areas (per SFR) of those material-finishes. Of course, the survey samples are assumed to be representative of the basinwide SFR population. (This representativeness assumption has been discussed in Section 3.4.1)

Table 3-19 provides a summary of the basinwide inventory of all material-finishes found in SFRs. (Although not included there, far more comprehensive inventories have been compiled in computer-generated tables submitted to ARB.) Since there are 2.25 million SFR parcels in the SoCAB, all exposed surface areas in the table are expressed in million square feet. In the SoCAB, there are about twenty billion square feet of exposed material surfaces of all types of items (except for enumeration items, for which separate estimates are made and discussed later in this section). OLD, MED and NEW periods of Los Angeles County account, respectively, for 19, 33 and 10 percent of the basin total while Composite County accounts for 38 percent.

In the SoCAB, wood, stucco, concrete, asphalt shingle and block are the five preponderant materials. Their combined total (including painted and stained as well as bare) accounts for 68 percent of all exposed material surfaces. Table 3-20 shows total painted surface areas by material. In the SoCAB, wood and stucco account for, respectively, 47 and 43 percent of the total painted material surface. Painted metals such as aluminum, steel and iron account for 6 percent and earthy materials such as block, brick, and concrete account for another 2 percent of the total painted material surface, which, in turn, amounts to 35 percent of the total exposed surface area of all material-finish combinations.

TABLE 3-19. BASIN TOTAL EXPOSED SURFACE AREAS BY MATERIAL-FINISH FOR SFR STRATA (All values in 10^6 ft^2)

	Material-Finish	OLD (443*)	MED (761)	NEW (211)	L.A. (1415)	COMP (834)	SoCAB (2249)
111	Block - Bare	139	489	167	791	447	1237
112	Block - Painted	19	17	9	45	1	47
121	Brick - Bare	184	151	42	379	149	529
122	Brick - painted	4	24	4	31	6	37
131	Concrete - Bare	455	683	293	1431	802	2233
132	Concrete - Painted	39	59	4	103	30	133
141	Stucco - Bare	106	100	55	263	414	679
142	Stucco - Painted	593	1138	322	2053	985	3036
151	Tile - Bare	-	3	1	4	3	7
152	Tile - Painted	-	-	2	2	-	2
161	Terra Cotta - Bare	101	-	86	188	213	400
181	Cement Shingle - Bare	57	-	-	58	104	164
391	Unspecified Stone - Bare	17	26	9	52	19	71
411	Aluminum - Bare	35	53	25	113	56	170
412	Aluminum - Painted	58	132	18	208	111	319
421	Anodized Aluminum - Bare	1	2	1	4	5	9
431	Aluminum Screen - Bare	19	36	3	57	17	74
441	Steel - Bare	1	2	-	3	6	9
442	Steel - Painted	8	9	3	20	6	26
451	Galvanized Steel - Bare	16	27	3	45	18	63
452	Galvanized Steel - Painted	11	21	4	37	13	50
461	Iron - Bare	-	-	-	-	-	-
462	Iron - Painted	9	17	5	31	12	43
471	Chain Link - Bare	115	190	77	382	271	653
501	Chicken Wire - Bare	3	8	2	13	37	50
591	Unspecified Metal - Bare	1	4	1	6	1	7
592	Unspecified Metal - Painted	2	4	1	7	2	9
611	Nylon - Bare	1	-	-	1	-	1
711	Wood - Bare	148	239	51	439	509	948
712	Wood - Painted	661	962	339	1964	1390	3354
715	Wood - Stained	33	21	21	76	64	140
721	Wood Shingle - Bare	-	524	143	659	798	1457
722	Wood Shingle - Painted	28	-	-	28	-	28
725	Wood Shingle - Stained	2	-	-	3	-	3
731	Plastic - Bare	2	-	-	3	-	3
741	Vinyl (hard) - Bare	-	2	2	4	-	4
742	Vinyl (hard) - Painted	-	-	-	-	-	-
751	Tar - Bare	76	324	42	440	177	617
761	Asphalt - Bare	20	242	13	275	82	357
771	Asphalt Roofing - Bare	748	977	225	1950	753	2703
781	Glass - Bare	104	176	54	334	181	515
791	Fiberglass - Bare	14	30	4	47	13	60
801	Fiberglass Screen - Bare	42	60	21	123	73	196
811	I/O Carpet - Bare	4	8	8	18	6	24
	Total Area	3878	6759	2058	12,697	7776	20,474

* Number of parcels in thousands.

Note: Due to round-off errors, the sum of elements may not equal the total.

TABLE 3-20. BASIN TOTAL PAINTED SURFACES BY MATERIAL IN SFR STRATA (All values in 10^6 ft^2).

Material*	OLD (443*)	MED (761)	NEW (211)	L.A. (1415)	COMP (834)	SoCAB (2249)
Block	19	17	9	45	1	47
Brick	4	24	4	31	6	37
Concrete	39	59	4	103	30	133
Stucco	593	1138	322	2053	985	3036
Tile	-	-	2	2	-	2
Aluminum	58	132	18	208	111	319
Steel	8	9	3	20	6	26
Galvanized Steel	11	21	4	37	13	50
Iron	9	17	5	31	12	43
Unspecified metal	2	4	1	7	2	9
Wood	661	962	339	1964	1390	3354
Wood Shingle	28	-	-	28	-	28
Painted Total	1432	2383	711	4529	2556	7084
All Finishes	3878	6759	2058	12,697	7776	20,474

Note: Due to round-off errors, the sum of elements may not equal the total.

* Number of Parcels in thousands

Table 3-21 shows the numbers of enumeration items by type for SFR strata. The table also indicates the average number per house for each item type. The most numerous item is light fixtures (1.8 items per house), followed by medium size antennas (0.51 items per house) and circular roof vents (0.38 items per house). Table 3-22 summarizes material-finish areas for these enumeration items. These values were arrived at only after elaborate measurements were made for test cases in the field or items of the same type at hardware stores. A more complete list of all types of enumeration items encountered in this study is given in Appendix G.

TABLE 3-21. NUMBER OF ENUMERATION ITEMS BY TYPE IN SFR STRATA.

Item	OLD (40)	MED (66)	NEW (18)	L.A. (124)	COMP (74)	SoCAB (198)
Antenna - Large						
Total Counts	1	6	2	9	12	21
No./house	.03	.09	.11	.07	.16	.11
Antenna - Medium						
Total Counts	25	39	5	69	31	100
No./house	.63	.59	.28	.56	.42	.51
Antenna - Small						
Total Counts	9	12	3	24	12	36
No./house	.23	.18	.17	.19	.16	.18
Circular Roof Vent						
Total Counts	14	29	4	47	28	75
No./house	.35	.44	.22	.38	.38	.38
Evaporative Cooler						
Total Counts	1	6	0	7	2	9
No./house	.03	.09	.00	.06	.03	.05
Light Fixture						
Total Counts	61	110	48	219	132	351
No./house	1.53	1.67	2.67	1.77	1.78	1.77
Pool Plumbing						
Total Counts	3	5	5	13	7	20
No./house	.08	.08	.28	.10	.09	.10
Roof and Ground A/C						
Total Counts	5	13	6	24	29	53
No./house	.12	.20	.33	.19	.39	.27
Satellite Dish						
Total Counts	0	1	1	2	2	4
No./house	.00	.02	.06	.02	.03	.02
Skylight						
Total Counts	1	5	0	6	9	15
No./house	.03	.08	.00	.05	.12	.08
Solar Panel						
Total Counts	8	9	2	19	24	43
No./house	.20	.14	.11	.15	.32	.22
Wall A/C						
Total Counts	16	27	1	44	13	57
No./house	.40	.41	.06	.35	.18	.29

TABLE 3-22. MATERIAL-FINISH SURFACE AREAS FOR ENUMERATION ITEMS ASSOCIATED WITH SFRs (All values in square feet per item).

Enumeration Item	Galv. Steel	Painted Steel	Bare Aluminum	Painted Aluminum	Copper	Glass	Plastic
Antenna - Large	5.2		3.2				
Antenna - Medium	2.6		3.2				
Antenna - Small	1.0		0.8				
Circular Roof Vent	5.1						
Evaporative Cooler		51.8					
Light Fixture		0.2				1.0	
Pool Plumbing		53.0			4.6		
Roof & Ground A/C		43.6					
Satellite Dish		4.7		56.6			
Sky Light							10.0
Solar Panel		30.0			3.4		24.0
Wall A/C Unit		13.7					

By combining Tables 3-21 and 3-22, VRC estimated basin total exposed surface areas by material-finish, as shown in Table 3-23. Although these surface areas are in general much smaller than those of non-enumeration items, for three material-finishes the exposed areas so estimated are larger than those of non-enumeration items: 67 million ft^2 vs. 26 million ft^2 for painted steel; 3 million ft^2 vs. none for bare copper; and 11 million ft^2 vs. 3 million ft^2 for bare plastic.

TABLE 3-23. BASIN TOTAL EXPOSED SURFACE AREAS OF ENUMERATION ITEMS IN SFRs (All values in 10^6 ft^2).

Material-Finish	OLD (443*)	MED (761)	NEW (211)	L.A. (1415)	COMP (834)	SoCAB (2249)
Galvanized Steel - Bare	1.7	3.3	0.5	5.6	3.4	9.0
Steel - Painted	10.1	21.2	7.2	37.4	29.9	67.3
Aluminum - Bare	1.0	1.8	0.3	3.1	1.7	4.8
Aluminum - Painted	-	0.8	0.7	1.6	1.4	3.0
Cooper - Bare	0.4	0.6	0.4	1.4	1.3	2.7
Glass - Bare	0.7	1.3	0.6	2.5	1.5	4.0
Plastic - Bare	2.3	3.2	0.5	5.9	5.1	11.0

* Number of parcels in thousands

4.0 NON-SINGLE FAMILY RESIDENCES (NSFRs)

4.1 GENERAL

Unlike SFRs, non-single family residence (NSFR) buildings vary greatly in both sizes and usages, making the survey design and on-site measurements more difficult than those for SFRs. As discussed in Section 2.2.2.2, VRC elaborated the survey design by delineating NSFR use types and the number of NSFRs in each use type from tax assessor records of the four counties and by carefully selecting study sites from the 20 mapbook areas in Los Angeles County and the 10 mapbook areas in Composite County. These study sites were selected so that their NSFR parcels (13,958 in L.A. and 21,432 in Composite) collectively mimic the use-type mixes of the two counties.

Both the previous ARB study (Murray et al 1985) and the NAPAP study (Merry and LaPotin 1985) were very sketchy about NSFRs. The previous ARB study made indirect measurements of construction materials through use of the Sanborn maps of selected buildings and the MacRae Industrial Directory. Unfortunately, the Sanborn maps (primarily used for fire insurance assessment) were often outdated (e.g., 10 years old) and were not available for all buildings. The NAPAP study, which used "footprint" as a basic sampling unit, ended up with so few non-residential samples that they could not draw any meaningful interpretation for the nonresidential building population as a whole.

Recognizing the difficulty of doing on-site observation of NSFRs and the futility of indirect measurements through existing maps such as the Sanborn maps, VRC and its sub-contractor, the San Jose State University (SJSU), decided to undertake an innovative method of airphoto analysis for identifying and quantifying materials associated with NSFRs. We term this method the "Airphoto Method" because it is based on techniques of airphoto analysis developed through numerous military applications. The airphoto method is an integrated method of airphoto taking, material identification through structural categorization, and quantitative measurements of features appearing on air photographs through use of supporting information such as cadastral maps showing the study objects.

This method was selected for the non-SFR's because the advantages it afforded far outweighed the marginal disadvantage of not making direct observations in the field of each inventoried building. The advantages of the method are:

- Far more buildings could be examined on aerial photographs than would be possible by visiting each sample structure in the field; measurements of construction materials and features were made of a total of approximately 2,000 buildings sitting on 899 parcels. Field visits by automobile to each parcel in each of the thirty sites - selected from throughout the South Coast Air Basin (SoCAB) in locations ranging from Van Nuys in the northwestern part to Riverside in the eastern end of the Basin, to Anaheim in the southeast - would have constituted an unacceptably large task.

- Aerial photographs present a synoptic view of buildings, one that is unattainable from the ground. In addition to being able to see roof materials and features, e.g., air conditioners and vents, that a ground-based observer cannot see (especially on flat roofs of buildings with parapets), the observer of the air photograph can readily see other features on the ground that may be hidden to the field worker (such as doors and windows at the rear on a building located within a large piece of fenced property that a field worker could enter only with special permission).

- Mensuration (measurement) of building dimensions is readily and accurately accomplished from the photographs. The scale of the photographs is standard; thus, for example, one millimeter on the photograph equals one meter on the ground, at a scale of 1:1000. Making measurements from photographs obviates the need for the common, time-consuming ground task of using a tape measure.

- All selected buildings may be observed from the photographs in a clinical manner without the need for gaining information from the owner of a structure. Indeed, identifying and contacting owners of non-single family residences is a difficult task in itself.

The obvious disadvantages of using aerial photographs as a data source are the inability to see and measure features that are too small to be discerned on the photograph and to make positive identification of building materials that are so similar in appearance that distinction cannot be made without personally visiting the building. Fortunately, few of these unresolvable identifications exist because the photo interpreter is able to use supporting information (see discussion of the branching key) that resolves most confusion. At the levels of generalization employed in the project, discrete types of building materials can be readily identified.

4.2 AIRPHOTO METHOD

The actual inventorying of building materials was preceded by several steps ranging from site selection through photo mission flying to photo interpretation. Each is described below.

4.2.1 NATURE OF THE TEST SITES

Measurements of building materials were made on randomly selected parcels from thirty sites located throughout the South Coast Air Basin (Figure 4-1); areas of all sites and numbers of parcels in each are given in Table 4-1. Twenty of the sites are in Los Angeles County, six are in Orange County, three in San Bernardino County, and one is in Riverside County; each is a map book from tax assessor records. They range in area from five (El Segundo, Glendale, East Los Angeles, West Hollywood, and El Monte) in Los Angeles County at 0.7 square kilometers to Buena Park at 7.9 square kilometers. The sites are representative of the type of diversity found in the SoCAB; some contain segments of centers of separate small towns, long since coalesced into the broad urban matrix. Others are drawn from more recently built areas; some of these are largely residential, some are nearly all industrial. A segment of the vertical air photograph of the Pasadena site (Figure 4-2) represents the type of land uses found in the sites. Commercial, industrial, and apartment buildings can be seen in the photograph.

Analysis of the generalized land uses found in the sites suggests placement of all of the sites within three broad groups (Table 4-2). The basis for distinguishing the groups is the percent of NSFR parcels falling

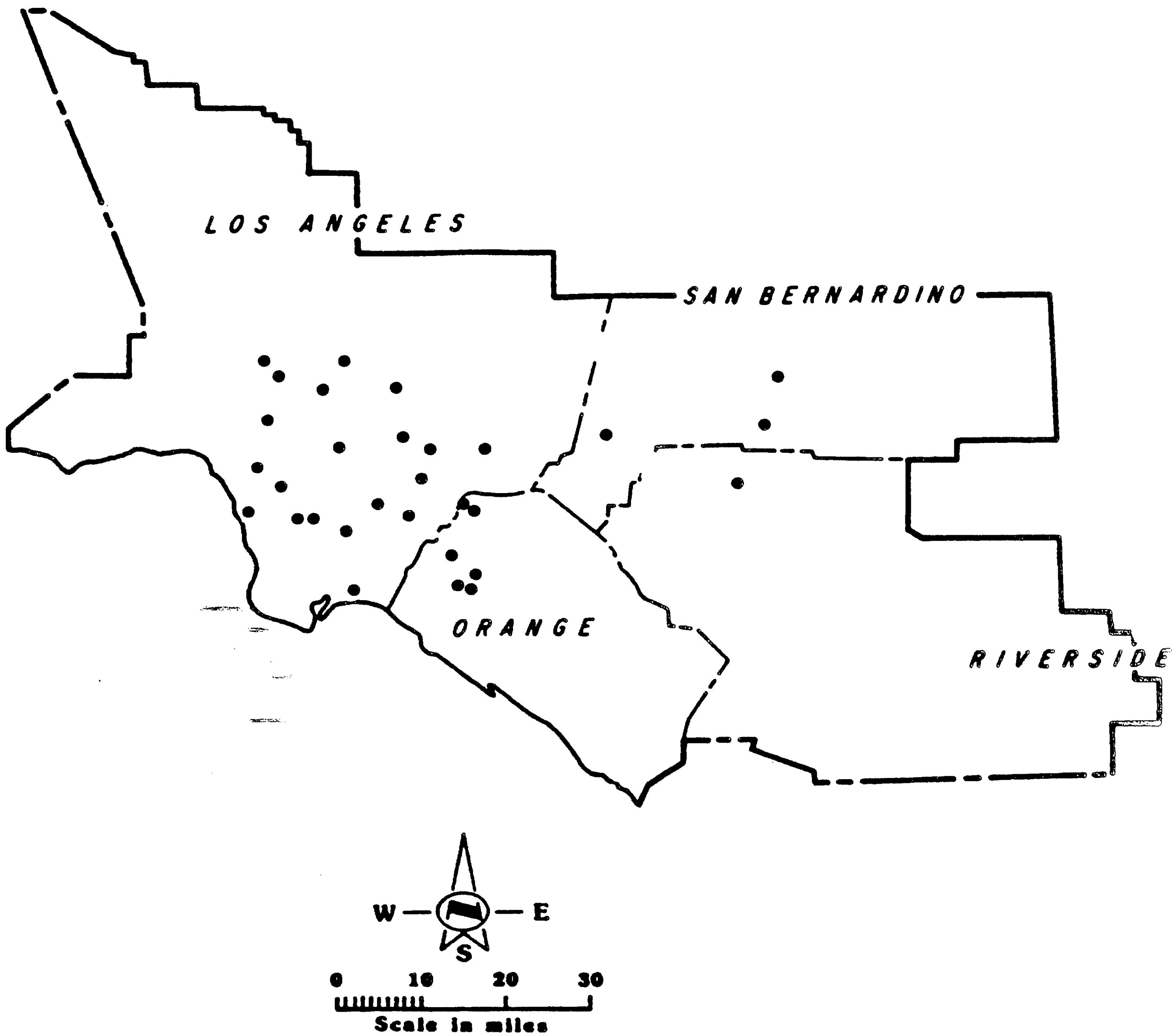


Figure 4-1. Location of the Thirty Sites in the South Coast Air Basin

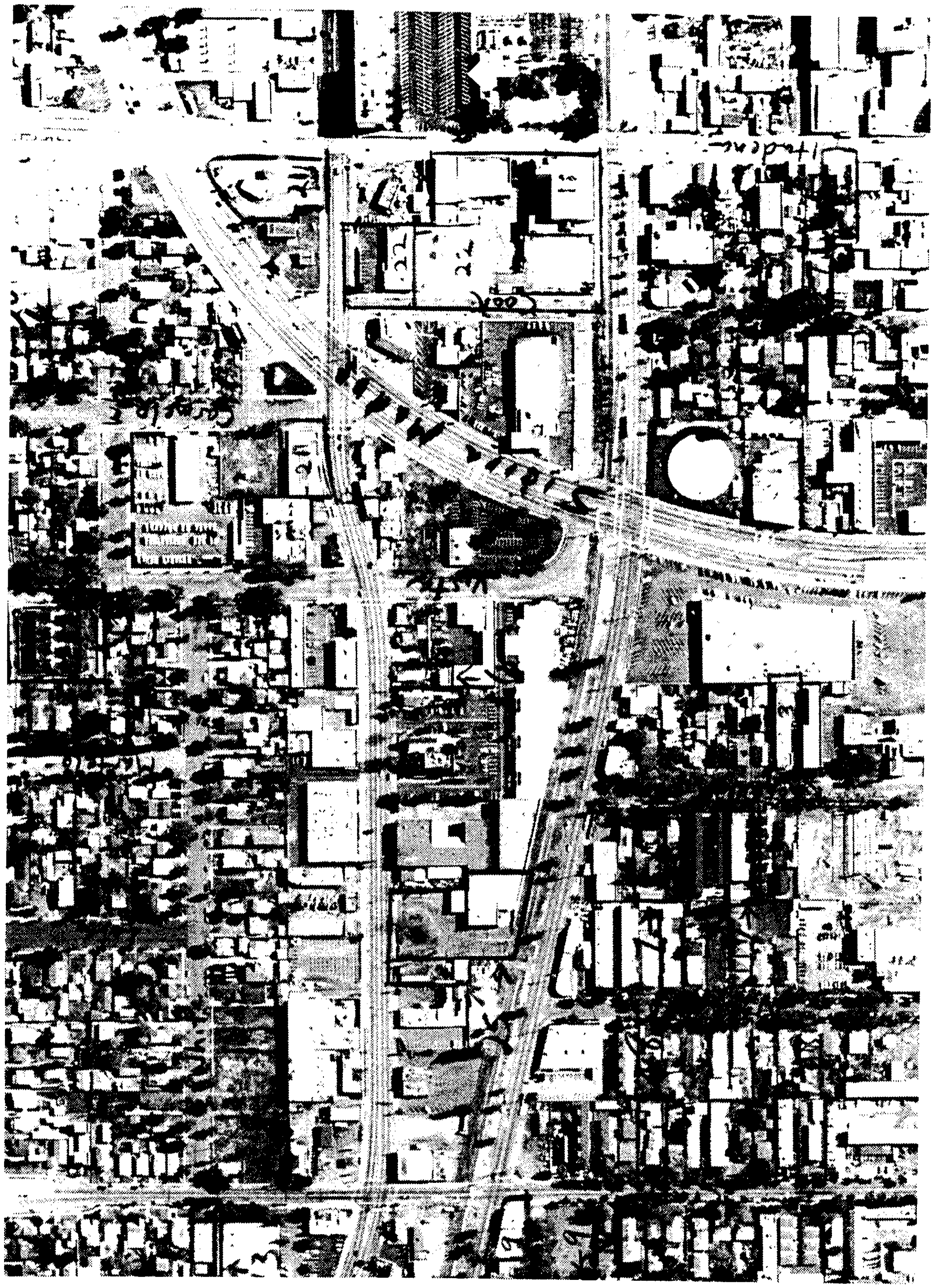


Figure 4-2. Vertical photograph of a segment of the Pasadena site. Commercial, industrial and apartment houses may be identified. A cadastral map (Figure 4-6) of part of the same area may be compared; both contain part of curving Sierra Madre Boulevard.

TABLE 4-1. SITE AREA AND NUMBER OF PARCELS PER SITE

Mapbook Site	Area of Site km^2	Number of Parcels SFRs	NSFRs	Total
Los Angeles County				
2321 Van Nuys	1.3	312	320	632
2353 North Hollywood	1.2	406	441	847
4016 Inglewood	1.1	181	355	536
4135 El Segundo	0.7	176	393	569
4252 Culver City	1.1	716	367	1083
4337 West Hollywood	0.7	379	365	744
5181 East Los Angeles	0.7	225	135	360
5283 San Gabriel/Rosemead	1.1	424	222	646
5695 Glendale	0.7	232	198	430
5746 Pasadena	1.1	324	368	692
5807 Montrose	0.9	374	333	707
6102 Gardena	1.3	30	329	359
6132 Compton	2.5	432	470	902
6251 Downey	1.1	500	216	716
7101 Paramount	1.1	563	235	798
7271 Long Beach	1.1	69	316	385
8026 Santa Fe Springs	2.6	669	338	1007
8104 El Monte	0.7	267	256	523
8139 Whittier	0.8	162	485	647
8743 West Covina	1.1	723	634	1357
Sub-Total	22.9	7164	6776	13940
Average	1.1	358	339	697
Composite County				
OR 022 La Habra	3.2	1414	384	1798
OR 070 Buena Park	7.9	3332	523	3855
OR 089 East Garden Grove	5.3	3129	730	3859
OR 129 Anaheim	2.7	1075	327	1402
OR 133 West Garden Grove	3.2	1806	353	2159
OR 298 La Habra	0.9	455	404	859
RV 219 Riverside	2.7	792	314	1106
SB 0141 Colton	5.8	581	1005	1586
SB 0154 San Bernardino North	6.9	2721	435	3156
SB 1011 Ontario	5.8	670	984	1654
Sub-Total	18.5	15975	5459	21434
Average	6.2	1598	546	2143
TOTAL SITES	41.4	23139	12235	35374

TABLE 4-2. SITE GROUPS AMONG THE THIRTY STUDY SITES.

Site/Group	# NSFR Parcels	Percent NSFRs*
SFR Dominated Sites		
Buena Park	523	13.6
San Bernardino North	435	13.8
West Garden Grove	353	16.4
East Garden Grove	730	18.9
La Habra (Pb 22)	384	21.4
Anaheim	327	23.3
Riverside	314	28.4
Paramount	235	29.4
Downey	216	30.2
Santa Fe Springs	338	33.6
Culver City	367	33.9
San Gabriel/Rosemead	722	34.4
Average	369	24.8**
Intermediate Sites		
East Los Angeles	135	37.5
Glendale	198	46.0
West Covina	634	46.7
La Habra (mb 298)	404	47.0
Montrose	333	47.1
El Monte	256	48.9
West Hollywood	365	49.1
Van Nuys	320	50.6
North Hollywood	441	52.1
Compton	470	52.1
Pasadena	368	53.2
Ontario	984	59.5
Colton	1005	63.4
Average	409	50.2**
NSFR Dominated Sites		
Inglewood	355	66.2
El Segundo	393	69.1
Whittier	485	75.0
Long Beach	316	82.1
Gardena	329	91.6
Average	376	76.8**
All Sites	12235	44.5**

* Percent of NSFR parcels to the total number of parcels in the mapbook.

** Average of individual NSFR percentages.

in either the broad class of SFRs or NSFRs, as based on functional classification assigned to parcels by the tax assessors of each of the counties; a more discrete separation is possible within Los Angeles County but distinctions among subdivisions of the two groups for the combined sites are obscured by the more generalized land-use classification used by the other counties.

SFR land use dominates in the first of the three groups of sites with an average, for the twelve sites, of 25 percent. At the other end of the scale, five of the sites are dominantly NSFR, with an average of 77 percent NSFR. The intermediate class, consisting of thirteen of the sites, shows an approximate balance between SFR and NSFR land use. None of the sites are purely one of the two land-use classes. The principal reason that these sites are not homogenous regions is that the boundaries of the tax assessor's map books are not intended to enclose homogeneous regions. Rather, they are major streets and boulevards that are readily recognizable as boundaries by the public being served. A common case is where commercial land uses, or apartment houses, face a bounding boulevard. Other land uses within the map book area are industries in some cases, multiple family residences in some, and single family residences in others; remaining uses are scattered throughout the sites.

4.2.2 PHOTOGRAPHIC SYSTEM

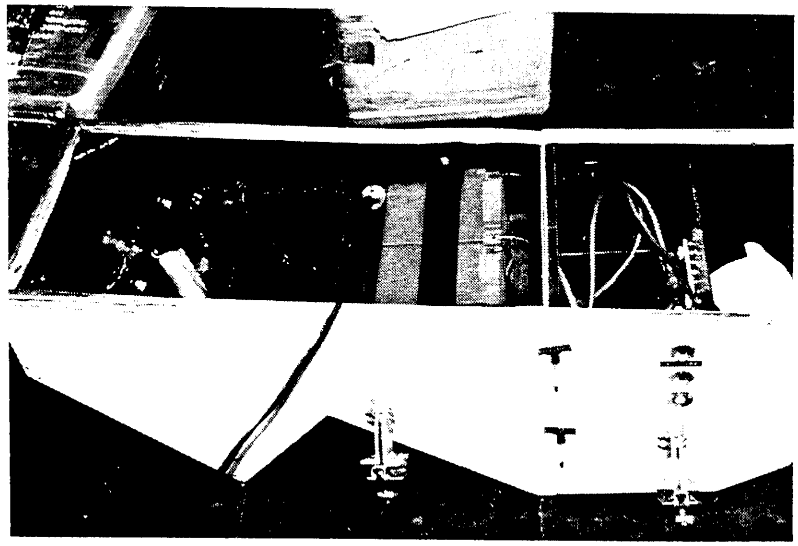
A necessary step before beginning the taking of Enviro-Pod oblique aerial photographs was a visit to each of the thirty sites to locate relative landmarks to use during the photo mission. In addition to ground visits, low-level flights were made over several of these to take hand-held photographs to compare with ground observations. These were used in the early phase of learning to identify building materials on the Enviro-Pod photographs.

The Enviro-Pod camera system. The Environmental Protection Agency office in Denver contributed to the project by lending a camera system and providing an expert to direct the operation. Mr. Dennis Nelson brought the camera system with him from Denver for the 10-day photography session in August, 1987.

The Enviro-Pod camera system is unique in that it provides for taking systematic, oblique photo coverage of large areas. (Most oblique photographs are single pictures of a site). For each of the thirty sites predetermined flight lines (approximately 1.5 kilometers apart) were drawn on large scale maps and followed during the actual flying mission; in a few instances, not all planned flight lines could be followed because of local air traffic restrictions near airports. The width of the flight lines followed was great enough to allow for sufficient sidelap; an intervalometer (which released the shutter at set intervals) inside the aircraft was set to allow ample overlap. For most of the sites, flight lines following the four cardinal compass directions were flown; flight lines were from East to West, West to East, North to South, and South to North). A total of approximately 2,000 exposures were made; seven rolls of 200 foot long Aero Ektachrome 2448 film were used. Picture size is 70 by 200 millimeters; a single role of film allows 300 exposures. Film and developing were contributed by the High Altitude Program at NASA's Ames Research Center at Moffett Field in Mountain View.

The camera mounted in the Enviro-Pod was an Air Force K85A reconnaissance model belonging to the Environmental Protection Agency. It was mounted, at a 45 degree angle, in the Enviro-Pod camera mount (see Figure 4-3). The Pod was mounted on the underside of the fuselage on a Cessna 182 aircraft hired at Mid Field Aviation, located at the Apple Valley Airport, near Victorville in the Mojave Desert. The panning lens of the camera may be seen in the upper part of Figure 4-4; the 45 degree downward look of the camera, through a glass port, is seen in the lower photograph.

Flying the mission. A period of ten days was required to complete the mission; excessive cloud cover precluded flying on one of the days. Dennis Nelson's time was contributed by EPA while the project paid his food and lodging. The missions were flown with a hired pilot at the controls of the aircraft, Dennis Nelson operating the camera, and Richard Ellefsen navigating the flight lines over the sites. As the camera mount has space for only one obliquely directed camera, the crew had to land at several different general aviation fields in the area to remove the camera with its exposed roll of film and replace it with a camera that had been pre-loaded before beginning



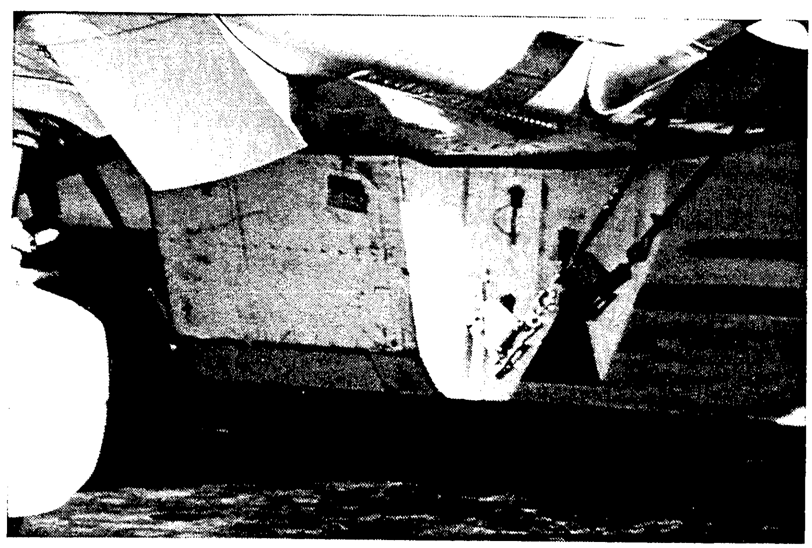


Figure 4-3. The above photograph shows the Enviro-Pod prepared for mounting on the bottom of the fuselage of the aircraft. On the left side, bottom, may be seen the 45° angled mount for a camera; the vertical camera can be mounted in the compartment on the right. The lower panel shows the Enviro-Pod in its mounted configuration; note the support straps connected to the seat rails inside the

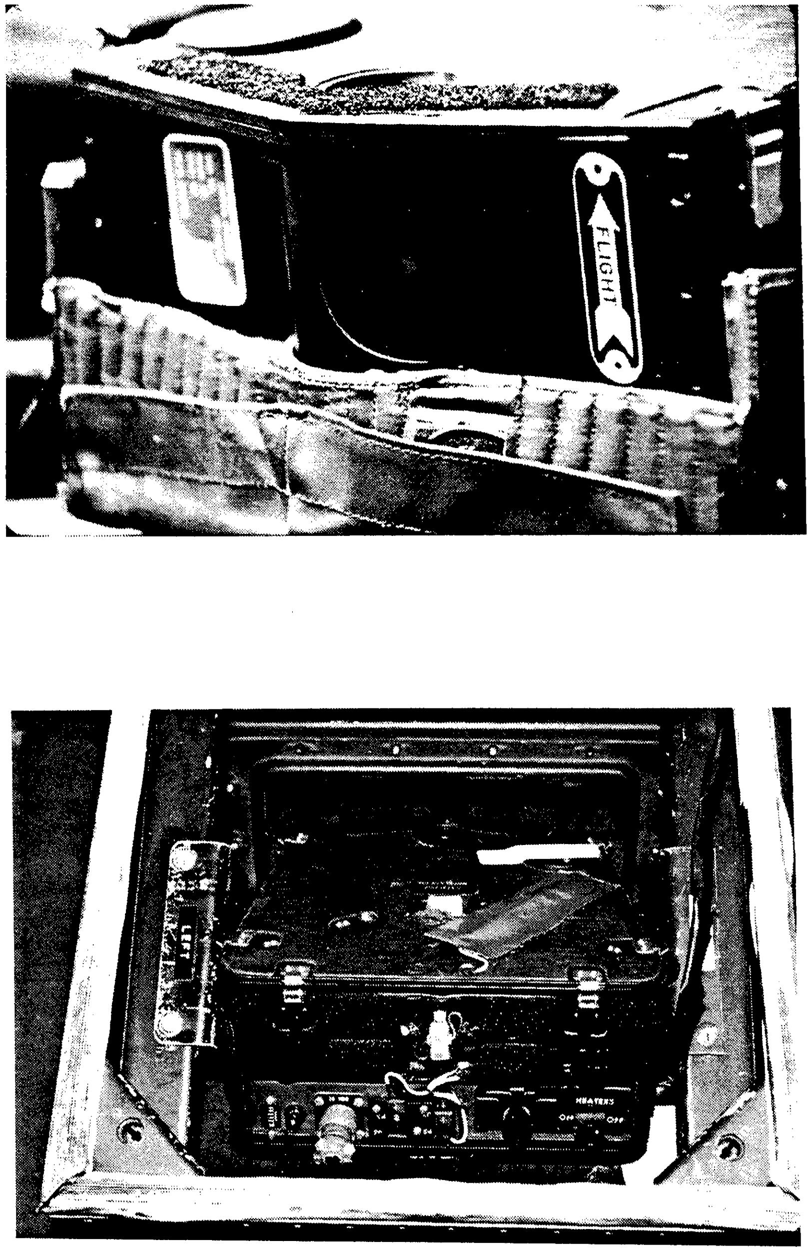


Figure 4-4. The upper panel shows the front of the camera with its panning lens; the lower shows the camera in the 45° angle bay.

the day's flying. This necessitated the task of removing the Enviro-Pod each time from the aircraft and then remounting it after changing cameras.

Film Processing. Upon completion of the flying mission, the film was brought to NASA's Ames Research Center for processing. The processed 200 foot long rolls were then taken to the Remote Sensing Laboratory at San Jose State University where each scene was identified, relative to the mission planning flight lines for each site, cut into individual exposures, and mounted in transparent plastic jackets for use by the interpreters.

The Enviro-Pod photographs. The pictures were all taken at the FAA minimum allowed flying altitude of 1,000 feet (with a normal, 80 mm focal length lens). This combination produced pictures that had the major attributes of: (1) showing all of the walls of the sample buildings plus roofs and other features (the 45° angle of the camera is optimum to negate any possible masking by nearby buildings); (2) sufficiently large enough scale (about 1:5000 at a photograph's center) to make necessary distinctions and identifications; and (3) excellent resolution to aid in identifying building materials. The example (Figure 4-5) of West Hollywood, even in this degraded half-toned form, demonstrates the high quality of the pictures; the original full color transparencies, viewed over a professional quality light table and with sharp optical magnification provide a high level of detailed information.

4.2.3 OTHER SUPPORTING MATERIAL

The project purchased, from an aerial photography firm, copies of black and white vertical air photographs of each of the thirty map book areas (see example in Figure 4-2). These were essential for making building perimeter measurements required to calculate areas. Scale of the pictures was approximately 1:3500; detail was sufficient for all needs.

Copies of the cadastral maps of the sites were used to make measurements of the parcels; the cadastral map (Figure 4-6) covers approximately the same area of Pasadena as seen in Figure 4-2. Used in conjunction with the vertical photographs and the oblique Enviro-Pod pictures, the analysts were able to make all the required measurements.

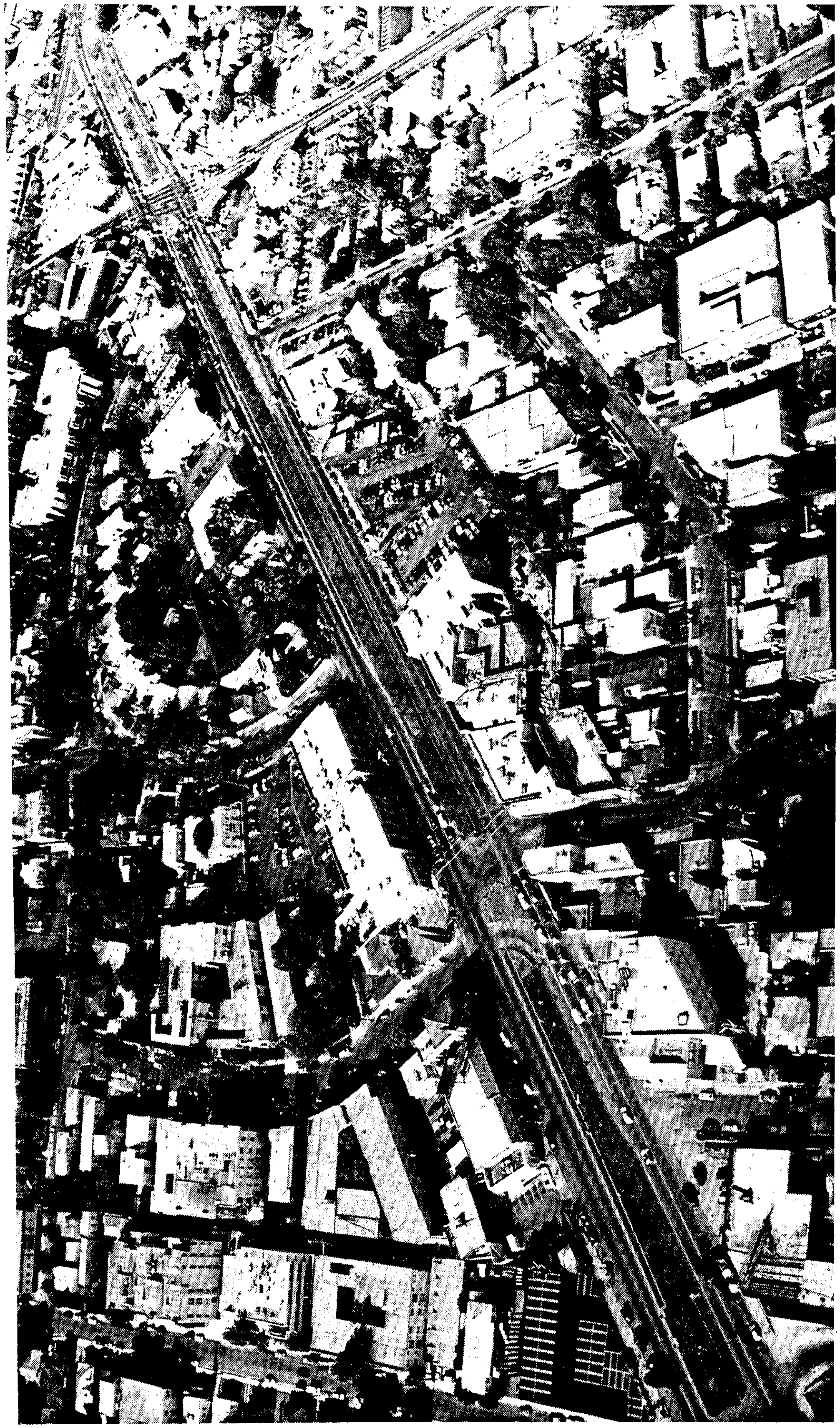


Figure 4-5. A black and white copy of the full color Enviro-Pod photograph. The covered area is at the northern end of the West Hollywood site; the major street is Santa Monica Boulevard. The view is looking northward and comes from one of the north-south flight lines. Note the detail of the roof features and that building height can be readily determined by counting stories.

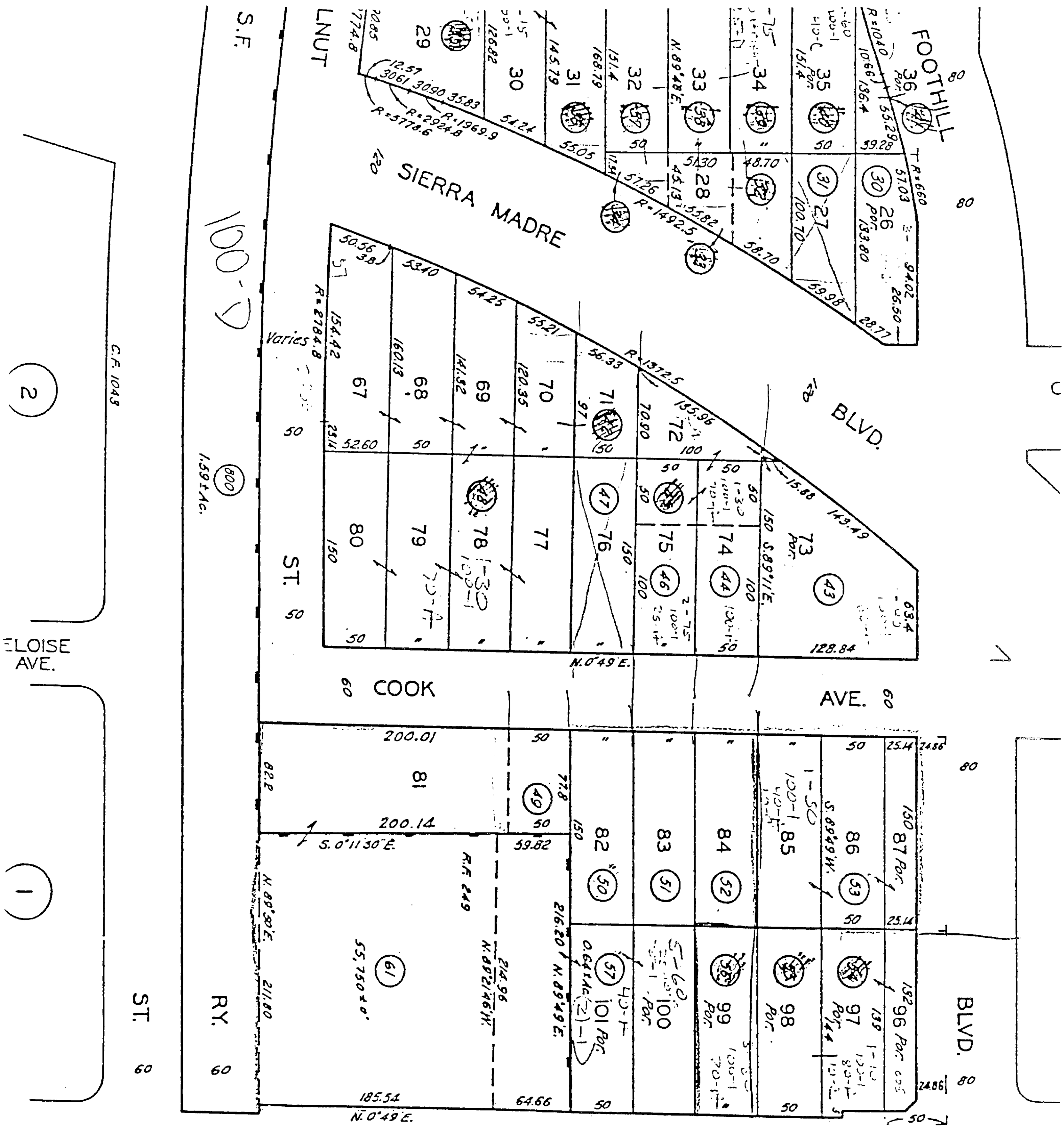


Figure 4-6. A segment of a cadastral map of Pasadena; it covers part of the area seen in Figure 4-2. Note the lot configurations and recorded dimensions of lot parameters.